BOARD OF STUDIES
NEW SOUTH WALES

1997 HSC

EXAMINATION REPORT

Engineering Science

Including:
- **Marking criteria**
- **Sample responses**
- **Examiners' comments**

Acknowledgment

Diagram: tow truck, from *Introduction to Engineering Mechanics*, Schlenker & McKern, John Wiley & Sons, 1976, p 182.

Diagram: VW car, from *Introduction to Engineering Mechanics*, Schlenker & McKern, John Wiley & Sons, 1976, p 273.

Diagram: police motorcyclist, from *Engineering Mechanics*, 2nd ed, Meriam & Kraige, John Wiley & Sons, 1976, p 218.

Diagram: Lawnmower air filter system, from *Victa Rotary Mowers*, *1955-84 Service & Repair Manual*, Gregory's Sci Publ No 220, 1984, p 24.

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Contents

Preface

The Enhanced Examination Report replaces the standard HSC examination report in selected subjects. It contains additional information and in this report, includes marking criteria, candidate responses and detailed examiners comments on aspects of questions asked in both the 2 and 3 Unit Examination Papers. In many cases, only the correct responses have been included due to the length prescribed for this report. It is meant to provide guidelines for the teaching and candidate preparation for the formal examinations.

In 1997 approximately 1,494 candidates sat for the 2/3 Unit Common Paper, and 216 students sat for the 3 Unit Paper. This year, the top 2 Unit result was achieved by a 3 Unit candidate.

The majority of candidates attempted all questions required and made a serious attempt at attempting answers. Some students displayed outstanding knowledge by their comprehensive and complete answers. This was a great encouragement to the markers, to see students who were fully prepared for the examinations.

I would like to thank all markers and Senior Markers for their effort and contribution to this first production. Special thanks go to Mr Edward Davies, Mr David Chapple and Mr Bruno Sciacca for their thoughtful and timely assistance in collating, checking and inputting data for this report.

I trust the report will be a useful document for teachers and students of Engineering Science.

Kevin Carter

Supervisor of Marking, 1997

ENGINEERING SCIENCE

SYLLABUS 2/3 Unit Engineering Science, published by the Board of Studies in 1994.

COURSE DESCRIPTIONS

Preliminary Course

120 (indicative) hours of school study.

- Graphics — descriptive geometry, orthogonal drawing, graphical mechanics
- Analysis — classification of materials, forces and statics, basic machines, dynamics, testing and strength of materials, metals, single and multi-phase materials, polymers, ceramics, composite materials
- Applications — an analysis of simple engineered systems.

The Preliminary Course is considered assumed knowledge for the HSC Course.

HSC Course

120 (indicative) hours of school study.

The course will use and further develop the assumed knowledge from the Preliminary Course.

- Graphics — descriptive geometry, orthogonal drawing
- Analysis — forces and statics, dynamics, testing and strength of materials, simple machines, classification of materials, metals, single and multi-phase materials, organic polymers, ceramics, composite materials
- Applications — an analysis of engineered systems, including the Prescribed Topics.

Reporting student achievement in the HSC

There are two marks reported on the HSC Record of Achievement for 2/3 Unit (Common) Engineering Science:

1. A moderated assessment mark out of 100 based on the student's performance in school assessment tasks.
2. A scaled examination mark out of 100 based on the student's performance in an external written examination of 3 hours' duration.

Each student's overall performance is reported as a percentile band which indicates their standing relative to other candidates presenting for this course. The percentile band is determined on the basis of the combination of the examination mark and the assessment mark.

3 Unit (Additional) Course

An additional 60 (indicative) hours of school study.

- Graphics — descriptive geometry
- Analysis — forces and statics, dynamics, testing and strength of materials, classification of materials, single and multi-phase materials, modification of materials, corrosion
- Applications — an analysis of engineered systems.

Reporting student achievement in the HSC

There are two marks reported on the HSC Record of Achievement for 3 Unit (Additional) Engineering Science:

1. A moderated assessment mark out of 50 based on the student's performance in school assessment tasks.
2. A scaled examination mark out of 50 based on the student's performance in an external written examination of $1\frac{1}{2}$ hours duration.

Each student's overall performance is reported as a percentile band which indicates their standing relative to other candidates presenting for this course. The percentile band is determined on the basis of the combination of the examination mark and the assessment mark.

SCHOOL ASSESSMENT GUIDE

Introduction

Assessment strategies should reflect the intentions of the syllabus objectives. The HSC Course components for assessment could be used as a guide or framework for the Preliminary Course.

Assessment programs should measure the extent to which each student has achieved the knowledge and skills outcomes outlined in the syllabus.

A range of assessment strategies must be used to assess student performance. Each strategy should be appropriate for the outcome it is designed to measure, and may measure more than one outcome.

Preliminary Course

The components that are used by schools in the formulation of School Assessment for the Preliminary Course are detailed below.

Component	Weighting
Graphics	30
Analysis	70
Marks	100

The Preliminary Course is considered assumed knowledge for the Higher School Certificate Course.

HSC Course

Assessment Requirements
2/3 Unit (Common) Engineering Science : a single mark out of 100
3 Unit (Additional) Engineering Science : a single mark out of 50

The assessment component of the Higher School Certificate is to be based on the HSC Course only.

Assessment for the Higher School Certificate will not begin until the completion of the Preliminary Course.

While the allocation of weightings to the various tasks set for the HSC Course is left to individual schools, the percentages allocated to each assessment component must be maintained. For each component, the assessment should be spread over several tasks throughout the course.

The assessment components for the 2/3 Unit (Common) Course and the 3 Unit (Additional) Course are **mandatory**.

HIGHER SCHOOL CERTIFICATE

EXAMINATION SPECIFICATIONS

General

- Answers to all questions are to be written in the spaces provided in the question paper.
- Where appropriate, emphasis will be placed on the method used when marks are allocated.
- The Data Formula Sheet included in each paper should be removed for convenience and used during the examination.
- Diagrams are drawn to scale unless otherwise stated. The scaled diagrams may be used if graphical solutions are attempted.
- Drawing instruments must be used for all graphical solutions and for drawing questions unless freehand methods are requested.
- All answers to questions based on the Graphics section of the syllabus must be drawn in pencil or black ink.

2/3 Unit (Common) Examination Paper *(100 marks)*

Time allowed: 3 hours (plus 5 minutes' reading time).

This paper is divided into two Sections.

Section I: Questions 1–6 *(48 marks)*

All questions are compulsory.

Four questions will be based on the Analysis section.

Two questions will be based on the Graphics section.

All questions are of equal value.

Section II: Questions 7–12 *(52 marks)*

Section II consists of six questions, based on the Prescribed Topics.

All questions are compulsory.

One question, worth 8 marks, will be based on the historical background of the Prescribed Topics.

FOUR questions, worth 8 marks each, will be based on the Analysis and Applications sections of the HSC Course syllabus.

ONE question, worth 12 marks, will be based on the Graphics (orthogonal drawing) section of the HSC Course.

3 Unit (Additional) Examination Paper *(50 marks)*

Time allowed: $1\frac{1}{2}$ hours (plus 5 minutes' reading time).

Students must attempt EIGHT questions.

Section I: Questions 1 and 2 *(20 marks)*

Both questions are compulsory.

The questions are based on the Analysis section.

Section II: Questions 3–6 *(15 marks)*

Candidates must attempt THREE of the FOUR questions (5 marks per question).

The questions are based on the Analysis section.

Section III: Questions 7–10 *(15 marks)*

Candidates must attempt THREE of the FOUR questions (5 marks per question).

The questions are based on the Graphics section.

Equipment List for 2 and 3 Unit

At the examination centre students will be provided with two desks at right angles for additional working space. Students must provide the following:

- a Board-approved calculator. Details of Board-approved calculators are published each year in the *Board Bulletin*;
- a drawing board, and T square to suit;
- two set squares (one 45 degrees and one 60–30 degrees);
- a set of drawing instruments;
- a metric rule;
- a protractor;
- pencils;
- erasers;
- drafting tape/drawing clips/drawing pins;
- drawing templates.

The use of drafting machines (non-programmable) is optional (Memorandum No 43/88).

Mechanical Drafting Machines ONLY are permitted.

Electronic devices such as Computer Assisted Drafting Systems are **not** permitted.

COURSE PRESCRIPTIONS

HIGHER SCHOOL CERTIFICATE EXAMINATION
1998 AND 1999

2/3 UNIT (COMMON) and 3 UNIT (ADDITIONAL) COURSES

The following systems have been nominated for the examination in Engineering Science. All of these topics are to be studied. Sections of the examination related to the detailed analysis of common applications will be drawn from **one or more** of these **Prescribed Topics**:

1. The Bicycle.
2. Brakes.
3. Domestic Lawn Mowers.

In issuing this list, the Syllabus Advisory Committee wishes to draw attention to the following:

A. Variation may occur in the list of prescribed topics from one year to the next by the addition, deletion or substitution of any **one or more** topic(s).

B. Providing advance knowledge of the types of engineered systems ensures that no student will be disadvantaged because of unfamiliarity with the general names, shapes and functions of the components selected for detailed analysis and graphical treatment in the examination.

C. The purpose of Section II of the HSC Examination for the 2/3 Unit course is to test the student's ability to think logically, through the use of the technique of analysis, about real systems, rather than his/her ability to recall large amounts of often unrelated factual material.

D. The intention is to provide common **applications** that test the content stated in the syllabus.

E. The historical background of any nominated topic is important as far as it demonstrates the developments in, or relationships between, social consequences, materials, manufacturing processes and the changing designs of these objects or systems.

PROCEDURES FOR HSC MARKING

THE MARKING PROCESS

The complete 2 Unit paper is split into Sections I and II. Section I is marked in Newcastle and Section II, along with the 3 Unit paper, is marked in Sydney. The markers are carefully selected from experienced teachers and university lecturers and are appointed to mark a specific question which relates to their area of expertise.

The Examination Committee presents a set of answers to the Supervisor of Marking for consideration. A meeting, between the Examination Committee, the Supervisors of Marking and the Senior Markers, is held to discuss and confirm the best answer for each question. The HSC markers further develop the range of accepted responses and marking scales for each question by pilot marking a range of scripts. The marking scales are examined and confirmed by the Supervisor of Marking before the red marking commences.

During the marking, questionable responses are analysed and discussed with the Senior Marker, and an appropriate mark is awarded. The Supervisor of Marking overviews the marking process to ensure the scales are correctly used and that all students receive equity. Marking scales may include checklists and concept lists. As the marking proceeds, each marker keeps a tally of the marks awarded for the question they are marking. These marker tallies are statistically examined each day and are used as a check, along with systematic checkmarking by the Senior Marker, to ensure the accuracy of the marking procedure. The control is such that the first candidate marked receives the same consideration as the last.

A correct solution for each question is contained in this report. It is impossible to provide a full range of answers for publication for any one question, as there are often many methods and combinations possible in providing a solution. For example, candidates may commence with an analytical solution, use a part graphical solution, and revert to an analytical solution to calculate an answer. Similarly, candidates may use auxiliary views, rebattment, or independent constructions to find true lengths of lines, all of which may provide the same solution. The marking scales are designed to provide flexibility, and to allow for alternative methods at arriving at a solution and to fairly discriminate between the Engineering Science candidates.

A report is prepared with marker comments and marking scales, for the information of the Examination Committee. This enhanced report includes comments made by Markers and Senior Markers on the responses given by candidates.

CLERICAL PROCEDURES

All candidates' scripts are kept in bundles according to each Examination Centre. Strict confidentiality is kept at all times. Scripts are distributed to, and collected from, markers by the Senior Markers. Senior Markers ensure that a marker does not mark papers from his/her school. It is not permitted for markers to find out the names of schools or centres they have marked.

ALLOCATION OF MARKS

Some general principles on the allocation of marks within each question is given below. They are points used in discussion and may be helpful in understanding how the marking scales are determined.

- An N/A (Not attempted) is awarded when there is no evidence (blank response) to any part of the question.
- A zero is awarded to an answer, which is not blank, and to which no marks are awarded. It is included in the statistics.
- Emphasis is placed on working when marks are allocated.
- Where possible marks are allocated on the basis of degree of difficulty, and to reward each correct response.
- Marks are attributed to correct and accurate use of technology.
- Conflicting information given in an answer is penalised, ie +1 -1 = 0
- Restating or rewording the information given in the question is not acceptable.
- When assessing diagrams, micro or macrostructures or graphs, they should reasonably reflect accepted practice of drawing such diagrams.
- When labels are applied to drawings they should be concise and specifically related to the diagram.
- Emphasis is to be placed on concepts/methods used.
- Concept errors are not awarded marks, however, errors made in one section of the paper, and carried forward to the next section, are not penalised twice. In Mechanics, providing the error carried forward does not make the answer any easier, then no penalty is applied.
- No marks are awarded for restating a formula given on the formulae sheet.
- Calculation errors are only applied once in a solution to a question.
- Marks are awarded rather than subtracted (positive response).
- Correct answers where no working is found are given full marks.
- Incorrect answer, no working, no marks.
- g = 10 m/s/s or g = 9.8 m/s/s or a graphical solution, are all acceptable in deriving an answer to a Mechanics question.
- The use of measurements (angles and distances) from scaled drawings in questions is acceptable.
- When more than one solution is shown, and one is crossed out, the solution not crossed out is marked.
- When one solution is given and crossed out, the solution is marked.
- When two solutions are given, one right and one wrong and an answer is not placed in the space provided, then marks awarded are at the discretion of the Senior Marker and Supervisor of Marking.
- Any solution to a problem not covered by the scale is to be brought to the attention of the Senior Marker for a resolution.
- It is acceptable for candidates to change the units on the paper, providing it conforms to SI standards. For example, 1200 N changed to 1.2 kN. Otherwise, units as indicated in the answer statement must be given.
- Projections in Graphics questions should not be erased, as these often display the method used in solving the problem. Marks are awarded for correct methods/concepts.

- Sectioning, linework and general standards related to Graphics are to conform to AS1100.
- Unless required in the question, labels for plotted points are not required.
- Evidence of calculating true lengths in triangulation problems should be expected. Analytical calculations are acceptable, but not encouraged.
- In intersection problems, end points and change-over points should be clearly shown. Joining points in correct order completes the ‘visibility’ of the view. Visibility is an important component of all orthogonal drawings.
- Candidates are expected to write sentences for questions that ask for definitions, descriptions or explanations. If the question asks the candidate to state, then a keyword is rewarded and a sentence is not expected.

Additional comments are included with each question.

STUDENT NUMBER

CENTRE NUMBER

BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1997
ENGINEERING SCIENCE
2/3 UNIT (COMMON)
SECTION I

(48 Marks)

Total time allowed for Sections I and II—Three hours
(Plus 5 minutes reading time)

DIRECTIONS TO CANDIDATES

- Write your Student Number and Centre Number at the top right-hand corner of this page.
- Allow approximately 90 minutes for this Section.
- Attempt **ALL** questions.
- Answer the questions in the spaces provided in this paper. **Set out your working clearly and neatly. Emphasis will be placed on that working when marks are allocated.**
- All questions are of equal value.
- **Diagrams throughout this paper are to scale, unless otherwise stated.**
- Drawing instruments and Board-approved calculators may be used
- A Formulae Sheet is provided on page 33.
- The Formulae sheet and Rough Work sheet will not be collected.

EXAMINER'S USE ONLY

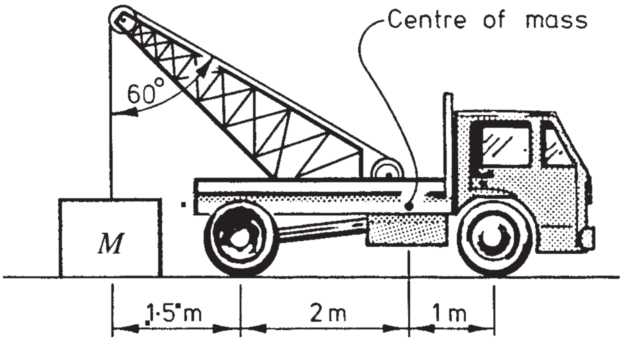
Question	Max Marks	Marks Awarded	Marks Checked
1	8		
2	8		
3	8		
4	8		
5	8		
6	8		
TOTAL	Max 48		

QUESTION 1

This question was generally well answered by the average candidate who seemed to understand most of the important concepts involved. The final part of the question allowed better candidates to obtain full marks.

Very few candidates used free-body diagrams. Examiners feel that greater understanding and better results would have been obtained by many candidates, had free-body diagrams been used.

(a) Details of a tow truck of mass 3 tonnes are shown on the diagram.



(i) Determine the maximum load, M, that could be safely lifted by this tow truck.

Maximum safe lift is when RFRONT = 0

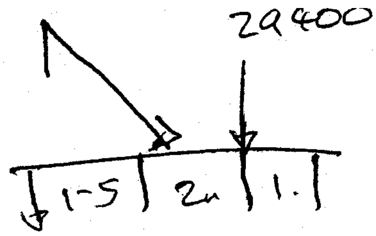
$M = 3\ t$ $\quad\quad$ $+\circlearrowleft\ \Sigma M_{REAR} = +(M \times 1.5) - (3 \times 2)$

$RF = 0$ $\quad\quad$ $M = 4\ t$

Maximum load M **4** *t*

Most candidates used moments to solve this question and the equilibrium concept $\Sigma M = 0$ was generally well understood. However many candidates had difficulty determining the correct pivot point to use (rear axle), which appears to suggest a poor understanding of the problem.

u –
v –
s –
a –
t –



$\Sigma F_V = 0 \quad + \uparrow$

$\Sigma F_H = 0 \quad + \rightarrow$

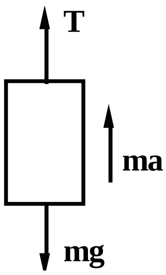
$\Sigma M = 0 \quad + \circlearrowright$

0

Maximum load M .... *t*

The most common problems were using the front axle or centre of mass as the pivot point. Other less frequent errors included the use of components of 60° in moment calculations. The angle was not required to be used and is a 'distracter'. Confusion of units of force and mass or in converting tonnes to Newtons to tonnes created simple mistakes.

(ii) For a different set of conditions, the cable uniformly accelerates a load of 1500 kg upward from rest at 0·3 m/s². Determine the maximum tension in the cable that occurs during this acceleration.



$m = 1500$ kg

$a = 0.3$ ms-2

$+\uparrow \Sigma F_v = T - mg = +ma$

$T = mg + ma$

$= 1500(9.8 + 0.3)$

$= 15\,150$ N

$= 15.15$ kN

Maximum tension **15.15** *kN*

On the surface this question appears to be a very basic question on unbalanced forces. Candidates familiar with the concept of unbalanced forces generally gained full marks. It was disappointing to see the number of candidates who treated this as an equilibrium question. Because the mass is accelerating there is a resultant force going up, as the tension in the cable exceeds the weight force of the block. The resultant force is given by $F = ma$.

The most common errors were $T = mg$ or $T = ma$. Other less frequent errors were $T = mg - ma$; $T = m \bullet g \bullet a$ and the use of *sin 60°* or *cos 60°* in calculations.

m ~~a~~ $= 1500$ kg
$u = 0$
$a = 0.3$ m/s²
$T = ?$
$\theta = 60°$

$T = ma$
$= 1500 \times 0.3$
$= 450$

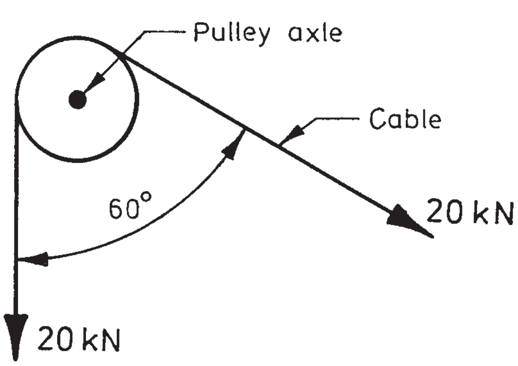
1

Maximum tension ....0.45.. *kN*

(b) An axle is used to support the pulley as shown on the diagram.

(i) For a different set of circumstances, the tension in the cable is 20 kN.

Determine the reactive force exerted by the pulley axle.



$+\neq \Sigma F_v = 0 = +R_V - 20 - 20\cos 60°$

$Rv = 30$ kN

$\overset{+}{\rightarrow} F_v = 0 = -RH + 20 \sin 60°$

$= 17.32$ kN

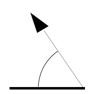
$R = \sqrt{30^2 + 17.32^2}$

$= 34.64$ kN

$\theta = \tan^{-1} \dfrac{30}{17.32}$

$\theta = 60°$

Reactive force *34.64 kN*

Direction *60°* 

This was the only part where a graphical solution is a viable option. Candidate responses were roughly equally divided between graphical and analytical with many attempting part graphical and part analytical solutions. Graphical solutions generally obtained better marks due to a high rate of mathematical errors made by candidates using analytical solutions. Students who used the sine or cosine rules invariably made calculation errors.

Other common errors included:

Placing the sense of the resultant in the opposite direction.

Using an incorrect force diagram.

Using incorrect angles.

Examiners noted a high number of candidates using compass directions in their answer, eg N 30° W. Showing the direction as in the correct solution given above is the preferred method. In this case the forces are all in a vertical plane not a horizontal plane. No marks were lost if compass directions were given.

(ii) For a different set of circumstances, the force on the pulley axle is 50 kN. Determine the minimum diameter of the axle if the maximum shear stress in the axle is 70 MPa. Assume that the axle is supported on both sides of the pulley.

$$F = 50 \times 10^3$$

$$\text{Max. Shear } \theta = 70 \times 10^6 \text{ Pa}$$

$$\text{Shear Area} = 2 \times \frac{\pi d^2}{4}$$

$$= \frac{\pi d^2}{2}$$

$$\sigma = \frac{F}{A}$$

$$A = \frac{F}{\sigma}$$

$$\frac{\pi d^2}{2} = \frac{F}{\sigma}$$

$$d = \sqrt{\frac{2F}{\pi\sigma}}$$

$$d = \sqrt{\frac{2 \times 50 \times 10^3}{\pi \times 70 \times 10^6}}$$

$$= 0.021 \text{ m}$$

$$= 21 \text{ mm}$$

Minimum diameter ***21*** *mm*

The majority of candidates only obtained part marks for this question. The most common errors were either ignoring or incorrect use of double shear. Almost as frequent was the lack of understanding of compatible units, the common errors being:

$A = \dfrac{50}{70}$ instead of: $\left(\dfrac{50 \times 10^3}{70 \times 10^6}\right) m^2$

Less frequent but still significant errors were:

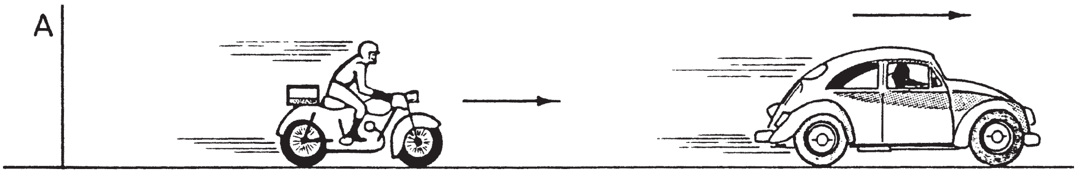
use of $r = \sqrt{\dfrac{A}{\pi}}$ and not converting to a diameter

Attempting to place all the information in one formula instead of solving it in steps resulted in a high rate of mathematical errors.

QUESTION 2

This was a basic question in dynamics involving distance, velocity, acceleration and time. The quality of the responses fell away towards the end of the question.

(a) A car, speeding at a constant velocity of 100 km/h, passes point *A* where a police motorcyclist is stationary. Two seconds later the motorcycle accelerates at a constant rate of 6 m/s^2 until it reaches 120 km/h. It then travels at this constant velocity.



(i) Determine the time taken for the motorcycle to reach 120 km/h.

$u_{mc} = 0$

$a_{mc} = 6ms^{-2}$

$v_{mc} = 120$ km/hr

$= 33.3\ ms^{-1}$

$v = u + at$

$$t = \frac{v - u}{a}$$

$$= \frac{33.3 - 0}{6}$$

$= 5.55$ sec

Time **5.55** *s*

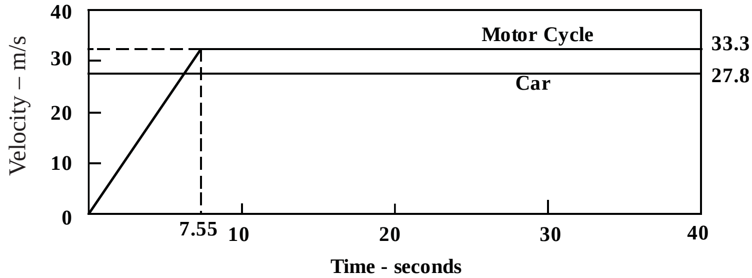
This was generally well answered with students stating the formula as v=u+at, substituting the correct data from the question to arrive at a time to reach a velocity of *120 km/h*. Many candidates failed to convert the velocity from km/h to m/s to allow them to correctly use the formula:

$$km/h = 10^3 / 60 \times 60$$

A small percentage of candidates included, unnecessarily, the two-second delay in time before the motorbike starts, ie *5.55 + 2 = 7.55 secs*. Marks were not lost if this was done.

(ii) On the axes shown below, plot and label the velocity–time graph for both the car and motorcycle for 40 seconds after the car passes point *A*.

$V_c = 100$ km/hr $= 27.8\ ms^{-1}$



This was well answered with the most common error of the motorcycle graph not commencing from 2 seconds on the time scale. Most realised that a constant velocity was a horizontal line on the graph, although some did not include this for the motorcycle. A few candidates did not realise that the constant acceleration is represented by a straight line. Graphing dynamics needs more attention by candidates.

(iii) Determine the distance travelled by the motorcycle in reaching 120 km/h.

$u_{mc} = 0$

$a_{mc} = 6$ ms-2

$t_{mc} = 5.55$ s

$$s = ut + \frac{1}{2}at^2$$

$$= 0 \times 5.55 + \frac{1}{2}\, 6 \times (5.55)^2$$

$$= 92.4 \text{ m}$$

Distance travelled ***92.4*** *m*

The distance could have been found by a number of methods. Few used the original data and substituted into $v^2 = u^2 + 2as$. The two most common methods was to find the area under the velocity - time graph or to use $s = ut + \frac{1}{2}at^2$

DISTANCE TRAVELLED TO REACH 120 km/h. = AREA UNDER GRAPH.

$A = \frac{1}{2} \times 33.3 \times 5.56$

$= \frac{185.19}{2}$

$= 92.6$ m

or

$a = 6$ m/s^{-1}

$u = 0$

$v = 33.3$ m/s

$s = ?$

$v^2 = u^2 + 2as$

$s = \frac{v^2}{2a}$

$s = \frac{33.3^2}{2.6}$

$= 92.6$ m

Distance travelled ......92.6...... m

Another method available was to use an average velocity method of:

$$\left(\frac{u + v}{2}\right)t$$

Errors made in part (i) when students did not convert km/h to m/s were carried through in parts (ii), (iii) and (iv) with no double penalty in marking.

(iv) Determine the distance between the motorcycle and the car, 10 seconds after the car has passed point *A*.

Distance of car:

$v_c = 27.8$ ms-1

$= 10$ s

For constant velocity:

$V_c = \frac{s_c}{t_c}$

$s_c = v_c \times t_c$

$s_c = 27.78 \times 10$

$s_c = 277.8$ m

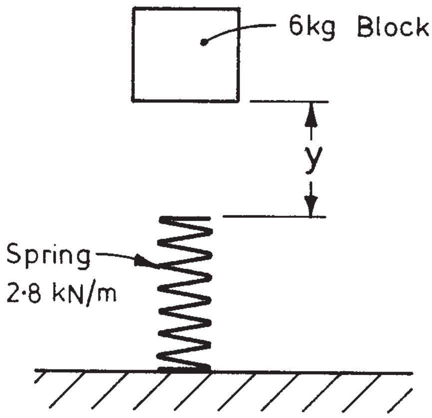
Distance of Motor Cycle:

Total distance	=	*dist. to 120 km/h + constant vel.*
	=	$92.4 + 33.3 \times 2.45$
t after 120 km/h = 2.4 s	=	$92.4 + 81.6$
	=	174 m
Difference in Distance	=	277.8 - 174
	=	103.8 m

Distance ***103.8*** *m*

The question contained several parts that needed to be combined. The distance that the car travelled with constant velocity was found by most candidates. The distance that the motorcycle travelled proved the most difficult with many candidates failing to realise that it travelled at a constant velocity before the 10 seconds had elapsed, ie after it had accelerated to 120 km/h. Many failed to realise that the initial wait of 2 seconds was necessary to be included in the calculations. Although it was possible, and expected, that candidates carried the distance calculated in part (iii) through to part (iv), many failed to do this and recalculated the distance again, often arriving at a different answer to what they calculated in part (iii).

(b) A 6 kg block shown in the diagram below is released from rest and falls through a vertical distance *y*. The block strikes the spring, compressing it by 100 mm. The spring constant is 2·8 kN/m. Determine the distance *y*.



$\Delta PE = \Delta$ *Strain Energy/Spring*

$\Delta PE = mg\,\Delta h = mg\,(y + 0.1)$

$$\Delta\ SE = \frac{1}{2}kx^2 = \frac{1}{2}k(0.1)^2$$

$$\therefore\ mg(y + 0.1) = \frac{1}{2}k(0.1)^2$$

$$y + 0.1 = \frac{\frac{1}{2}k(0.1)^2}{mg}$$

$$y = \frac{\frac{1}{2}k(0.1)^2}{mg} - 0.1$$

$$y = \frac{\frac{1}{2} \times 2.8 \times 10^3 \times (0.1)^2}{6 \times 9.8}$$

$$y = 0.138\ m$$

*Distance **138** mm*

Energy is conserved

$\therefore$ GPE = EPE

$mgh = \frac{1}{2}kx^2$

$6 \times 9.8 \times (y + 0.1) = \frac{1}{2} \times 2.8 \times 10^3 \times (0.$

$y = 0.138m$

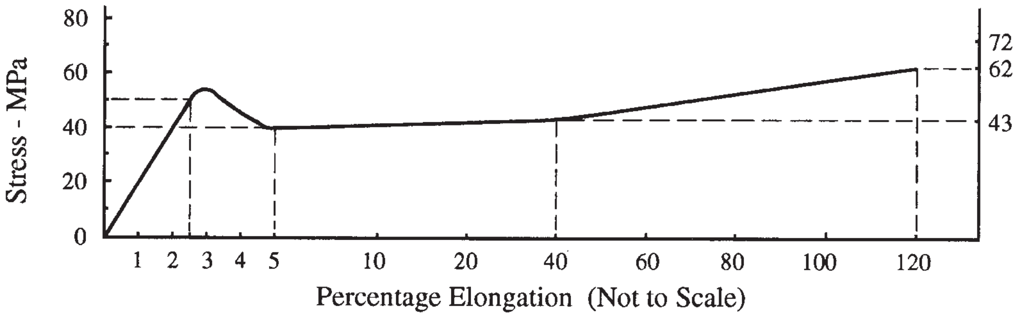
A very small number of candidates achieved full marks for this part. The use of strain energy in a spring was poorly understood and mostly not attempted. Candidates who did not equate the energy balance of potential energy and strain energy failed to calculate the potential energy correctly. Non-inclusion of the 100 mm distance in the potential energy calculations was common.

QUESTION 3

Most candidates had difficulty with this question, and this resulted in a mean raw score of approximately 4 for the question. The main problems were encountered in the first part of the question, Part (a).

Candidates were familiar with the concept, but had probably not tested or studied these materials in detail.

(a) Data from a tensile test on a polycarbonate sample are plotted on the stress and percentage elongation axes shown below.



(i) Determine the strain at the elastic limit.

$\% E \quad = 2.5$

$\therefore \varepsilon \quad = 2.5 \div 100$

$= 0.025$

Strain at the elastic limit 0.025 or 2.5%

Many candidates did not understand the concept of strain being expressed as a percentage elongation, however they should have been able to determine strain at the elastic limit from this graph. Many students were able to read 2.5% off the percentage elongation axes, which was marked correct, whilst others divided the 2.5% by 100 to achieve the acceptable answer of 0.025.

(ii) Data from a tensile test on a 10% glass-filled polycarbonate sample are listed below. On the stress–percentage elongation axes shown above, draw a possible curve from the given data for the 10% glass-filled polycarbonate sample.

- **UTS, 72 Mpa**
- **Modulus of elasticity, 3·1 Gpa**
- **Percentage elongation at fracture, 10%**
- **Stress at the elastic limit, 64 MPa**

$$E = \frac{\sigma}{\varepsilon}, \quad \varepsilon = \frac{64 \times 10^6}{3100 \times 10^6}, \quad \%E = 2.06\,\%$$

Most candidates achieved some marks for their graph, with very few gaining full marks. The main problem was the difficulty encountered in calculating the slope of the curve up to the elastic limit using Young's modulus. Firstly no space was provided for the calculation to be done, and secondly because polymers do not generally have a limit of proportionality. Many variations on the shape of the curve after the elastic limit were accepted as correct.

(iii) Polycarbonate and 10% glass-filled polycarbonate are both used in the manufacture of components for bicycle safety helmets.

The visor is tough and transparent, while the helmet is highly rigid and has good dimensional stability.

Determine which material would be used for the visor, and which material would be used for the helmet. Justify your answer, using the relevant data from the tensile tests and your knowledge of materials.

Visor material *Polycarbonate*

Justification *Flexible but tough and transparent. Toughness is indicated by the larger area under the graph.*

Helmet material *10% glass-filled polycarbonate*

Justification *Dimensional stability due to the addition of the glass fibre. Slope of the graph up to E.L. indicates the high rigidity. The material has a higher UTS, greater strength and is shatter proof.*

Many candidates experienced difficulty relating the properties of the polycarbonate and the 10% glass filled polycarbonate to the Stress-Elongation % curve. Many repeated the properties mentioned in the question without justifying their choice. Polycarbonate is tough because of its complex molecular structure, and as the chain is ‘lumpy’ the polymer is transparent. Filling the polycarbonate with glass fibre reinforces the structure, increasing the dimensional stability and rigidity.

Some candidates did not read the question carefully and instead of using the two given materials, they chose other materials such as perspex or bakelite to answer the question.

(b) (i) Define thermopolymer

Polymer which is softened by heat for its production and hardens when cooled. May be re-softened by heat.

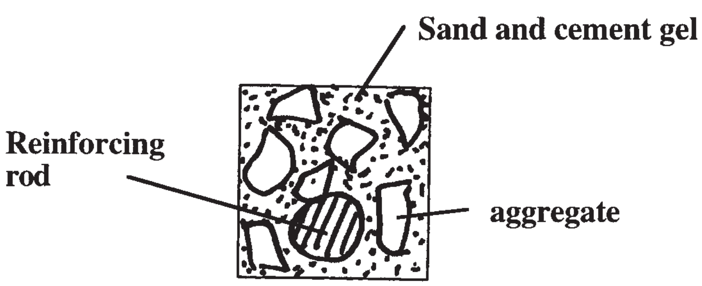
This definition proved difficult, because of the term ‘thermopolymer’, which means ‘thermoplastic’ or ‘thermosoftening polymer’. Many tried to define a polymer in terms of how it was produced as a product. Definitions of material groups, with examples is important in materials science.

(ii) Define condensation polymerisation

Formation of a polymer where there is a by-product such as water.

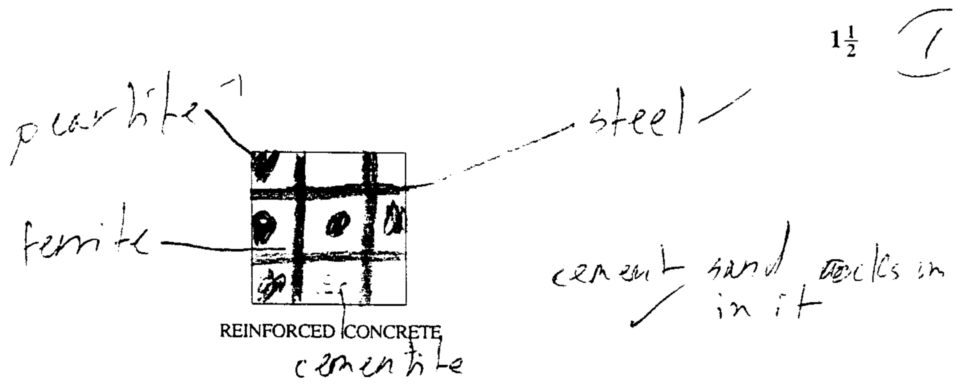
This section was well answered by the majority of candidates, who realised the ‘condensation’ was the formation of by-products from a polymerisation process.

(c) Draw and label the macrostructure of reinforced concrete.

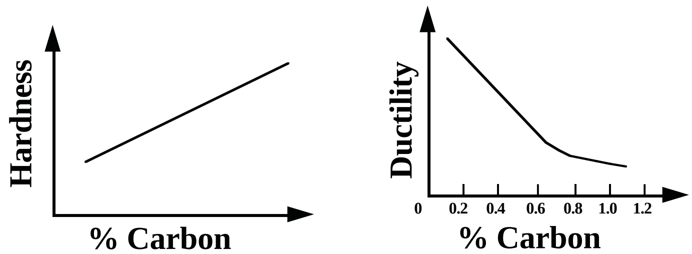


REINFORCED CONCRETE

The key elements of reinforced concrete that markers were looking for was reinforcing steel, coarse aggregate and fine aggregate held together by a cement gel. Some sketches and labels were very poor, indicating only ‘reinforcing’ and ‘concrete’, the information given in the question.



(d) The carbon content of steel in the annealed state affects the hardness and ductility of the steel. On the axes provided, graph the effect of increasing carbon content on hardness and ductility.



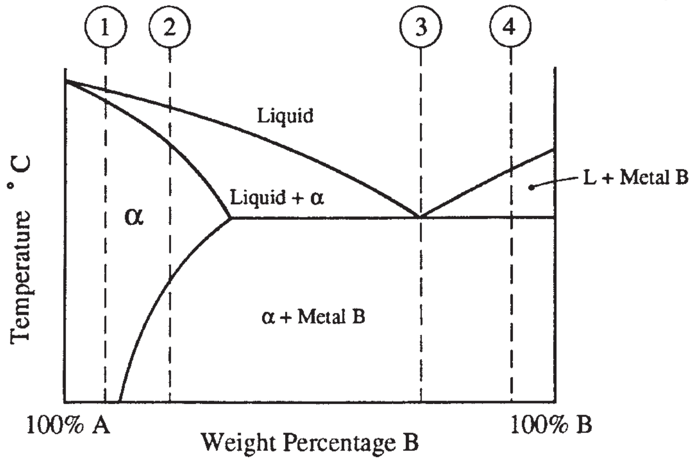
Most candidates answered this section quite well, showing hardness increasing with carbon content and ductility decreasing as carbon increases.

As carbon increases so to does the cementite in the structure. The phase field at room temperature is ferrite and cementite. As cementite is an interstitial compound it is hard and brittle, and as there is less ferrite as carbon increases, there is less soft and ductile ferrite.

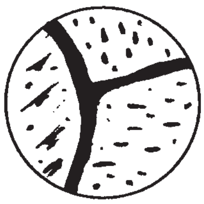
QUESTION 4

Candidates either knew equilibrium diagrams and microstructures and scored well, or otherwise had difficulty and scored poorly. Candidates need to understand the principles involved in phase diagrams, and be conversant in drawing and labelling microstructures, especially for materials studied in the course.

(a) The phase diagram for a binary alloy of metal A and metal B is given below.



(i) Alloy 2 and alloy 3 are cooled under equilibrium conditions to room temperature. Draw and label the resulting microstructures.



ALLOY 2

ALLOY 3

Generally well answered, although some candidates interpreted the phases present to be α and β, despite clear labels being supplied on the diagram (α and Metal B). Excessive labelling frequently lost marks for students introducing incorrect information. Be accurate and concise. Representation of the microstructure often poorly drawn, with grain size being too small. Some students incorrectly included ‘eutectic’ in their representation. Recommendation to students is to draw the alloy composition on the equilibrium diagram.

Alloy 2 was also considered below as an acceptable answer. It was characterised by slow cooling through the solvus line. The α would initially precipitate out along the grain boundaries along preferred planes, and along the grain boundaries. If time was sufficient (equilibrium cooling), then a more correct answer such as below left, would be the result. Faster cooling through the solvus could also produce a Widmanstatten Structure. Either of the three possibilities attracted marks.

Alloy 3 was generally well drawn and labelled. It should be noted that at room temperature, below the solidus line, the alloy is solid and would not contain ‘liquid’.

Equilibrium Cooled

Widmanstatten Structure

(ii) Alloy 1 and alloy 4 are cooled under equilibrium conditions to room temperature. Alloy 1 has a lower tensile strength than alloy 4. Explain, in terms of structure, the reason for this lower tensile strength.

Alloy 1 is a single phase, equiaxed grains of α. Alloy 4 contains two phases and includes eutectic of α and Metal B. Alloy 1 is more easily distorted under a tensile load because it has a single phase structure.

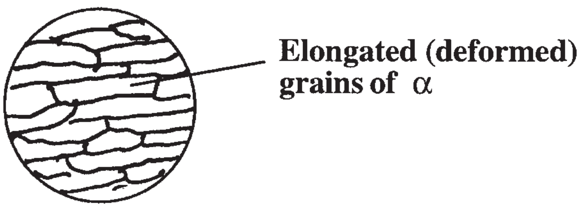
Quite commonly, single and two phase structures were mentioned but the explanation was poor. Some confusion existed between α solid solution and pure metal A in describing the structure. The strengthening effect of eutectic was rarely mentioned.

(iii) Alloy 1 is used for the manufacture of cold-drawn wire. State a mechanical property, other than suitable tensile strength, that enables it to be used for cold-drawn wire.

Ductility

Frequently candidates did not give a mechanical property, and others confused workability or malleability with ductility. The definition for ductility was given in the question.

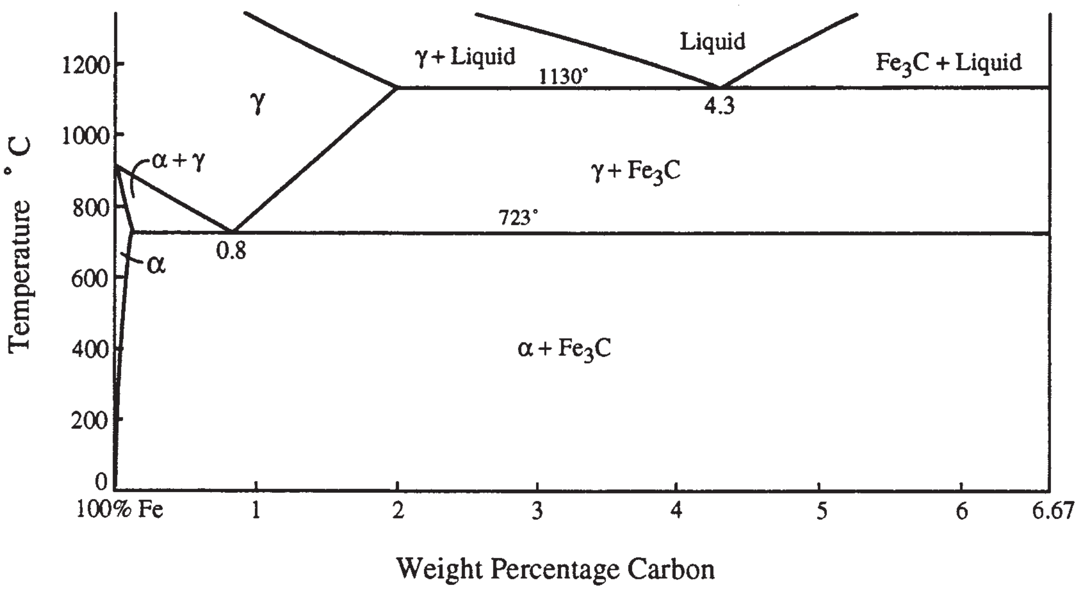
(iv) Draw and label the microstructure of alloy 1, following the cold-drawing process.



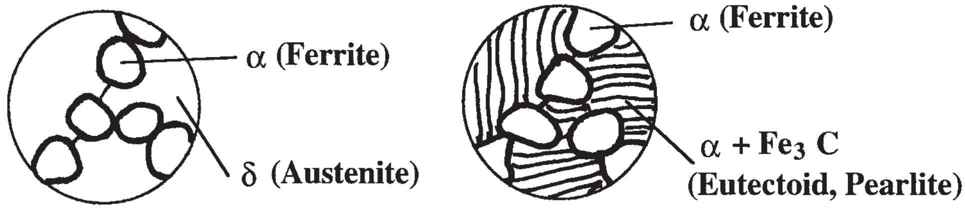
ALLOY 1 COLD DRAWN

Most candidates appeared to understand the process, but failed to represent elongated and deformed grains clearly. 'Voids', 'bricks' and 'sausage' shapes were often incorrectly used. Most textbooks on Materials Science have good examples of cold worked structures and should be consulted.

(b) Part of the iron–carbon phase diagram is given below.

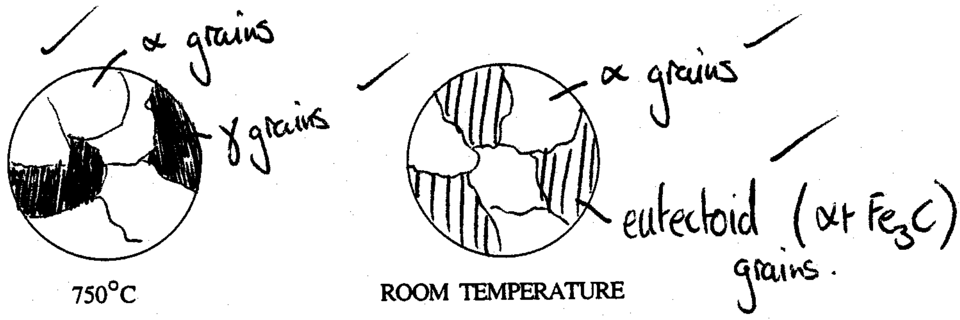


A sample containing 0·4% carbon is cooled under equilibrium conditions from 900°C to room temperature. Draw and label the microstructure at 750°C, and the microstructure at room temperature.



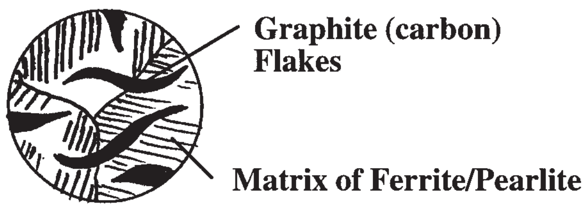
750°C ROOM TEMPERATURE

Microstructures at 750°C caused difficulty to some candidates, who included liquid phase and/or dendrites. Many had difficulty drawing austenite as an equiaxial grain structure. Eutectoid type structures were common. The phase field involved is α and γ (ferrite and austenite), and these are the only two phases that can be present for the stated circumstances. The ferrite precipitates from the austenite along the grain boundaries of the austenite.



Room temperature microstructure was generally well drawn, but labels reflected some confusion with eutectic and eutectoid, and Fe_3C phase rather than 'α and Fe_3C'.

(c) (i) Draw and label the microstructure of grey cast iron.



GREY CAST IRON

Drawings were generally well done, but the labels were often omitted or incorrect. The matrix in a grey cast iron can vary with composition, inoculants, and cooling history. The matrix can vary from a fully pearlitic structure to areas of ferrite and pearlite.

(ii) Explain, in terms of structure, why grey cast iron is weak in tension but much stronger in compression.

Sharp ends of flakes cause stress concentrations when material is subjected to a tensile load. The flakes do not act as stress risers under compression.

Candidates generally knew that the graphite flakes were involved, but were unable to explain 'why'. Frequently 'high carbon content' was given instead of the presence of graphite flakes in the structure. The role of graphite flakes as stress-raisers in weakening grey cast iron in tension, was more frequently understood than the increased compressive strength.

QUESTION 5

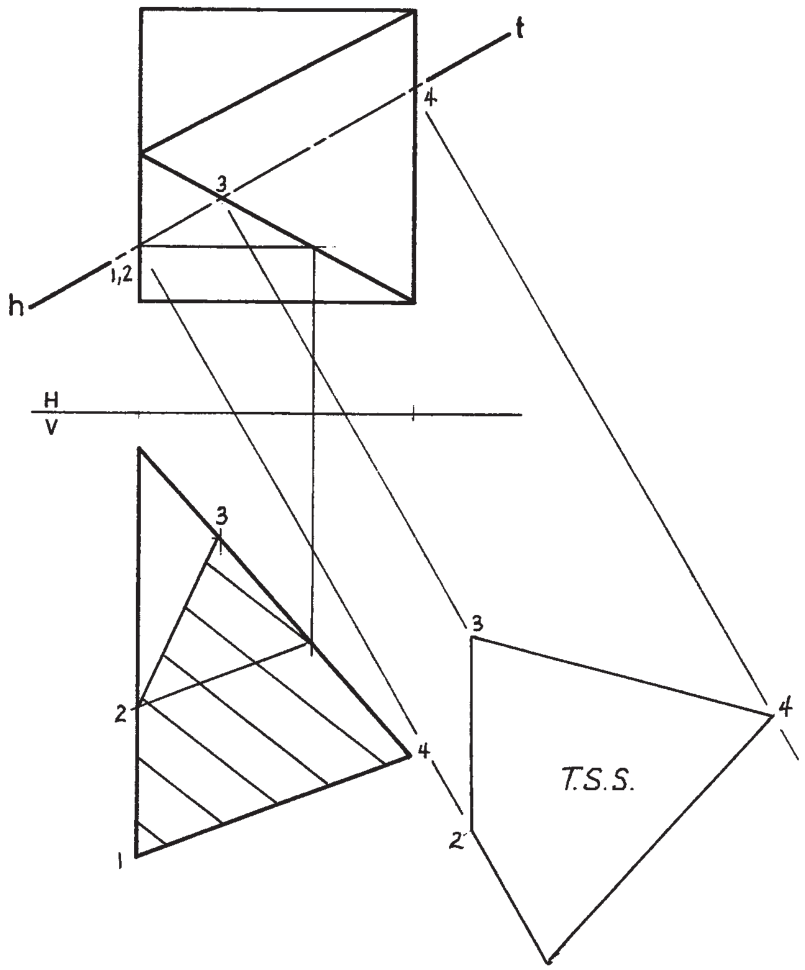
(a) The top view and incomplete sectional front view of a square pyramid, cut by a vertical section plane, are given below in third-angle projection.

(i) Complete the sectional front view.

(ii) Draw the true shape of section.

This question was generally well done, although many candidates failed to show working or construction. It is essential that construction be shown and not erased, as this displays the thinking and reasoning of the solution.

Some candidates experienced difficulty in visually interpreting the solid. This led to visibility line being either omitted or incorrectly drawn eg the horizontal edge 'el' and to point 3.



Identifying points in the front view projected from the top view was poorly done. Failure to identify projected points on the front view made the awarding of marks difficult. The standard of linework was generally good.

The location of point 2 on the slant edge of the section caused difficulty for many students. The use of vertical cutting planes in sectioned solids needs more attention by candidates. To locate point 2, candidates displayed a number of methods such as proportions of line length and analytical methods involving ratios. Projecting in the front view parallel to the base for the sample answer above, was poorly done. Point 3, by comparison was well done.

Many candidates found difficulty in defining the section limits, with line 2,3 and incorrectly joined the points with a centre line.

A large number of candidates failed to hatch the section in the front view. The TSS is not required to be hatched, unless it is found in a sectional view.

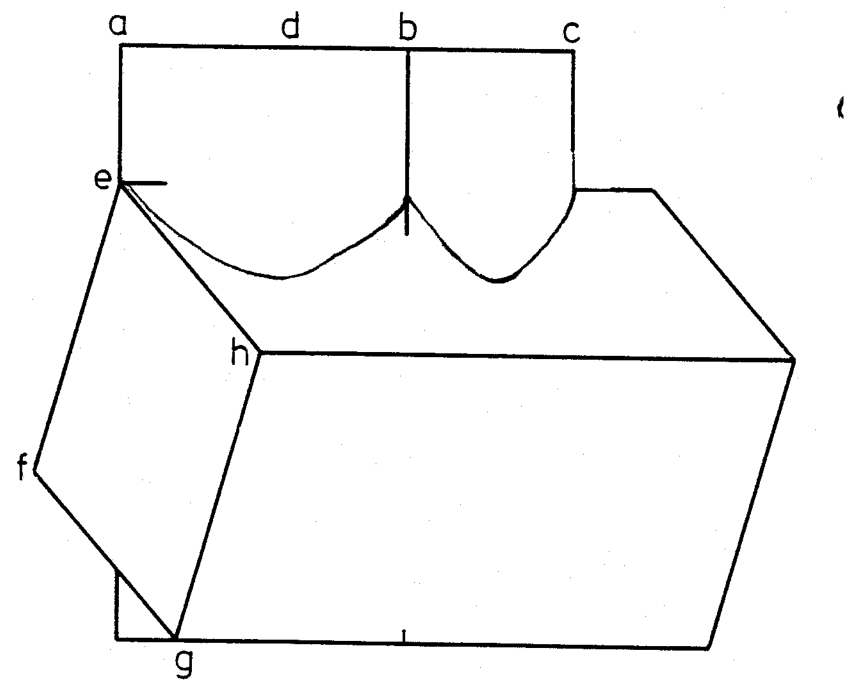
Drawing the TSS proved a difficult task for most candidates. Incorrect methods were used to find the points after projecting from the top view. The TSS can be found by projecting 90° to the section plane in the top view, then stepping off the distances of these points behind the vertical plane. As the TSS is part of a potential front view. The distances from the principal horizontal plane has to be the same as in the distances from the principal horizontal plane in the previous front view.

The solutions shown have been reduced to 70% of the original size.

(b) The top view and incomplete front view of two intersecting square prisms are given below in third-angle projection. Complete the front view, showing only visible outline.

This part was well attempted by most candidates, with a marked improvement in responses over part (a) of the question. The solution to the top half of the front view was more ably done than the lower portion.

A major misinterpretation was that some candidates did not understand the concept of a straight line of intersection resulting from two flat surfaces meeting. Several candidates drew curved lines of intersection.

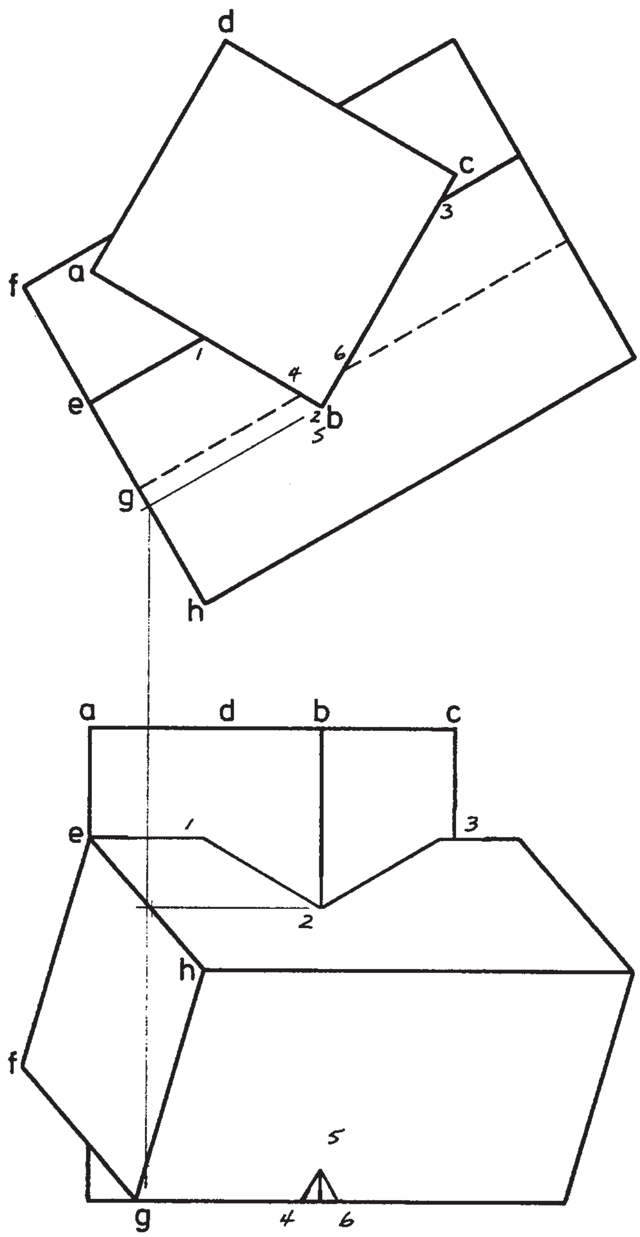


Many inaccuracies in projection were encountered, and while most candidates seemed to be able to visualise the final solution, difficulties were experienced in locating exact points.

Location of points 2 and 5 caused difficulties for many, with 5 being an obvious problem despite the same construction being used to locate 2.

Generally, points 4,5 and 6 were neglected by many which could be another indicator of a poor understanding of the application of vertical section planes.

Many students failed to extend vertical edges b2 and 5x in the ‘V’ or inverted ‘V’ or merely used the given edges.



QUESTION 6

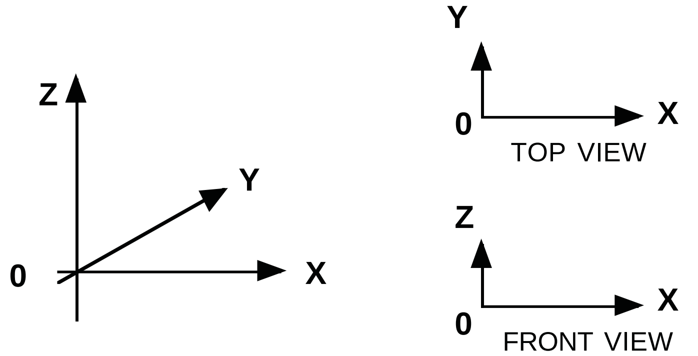
(a) The coordinates for the corners of a triangle *ABC* are given below.

	X	Y	Z
A	**15**	**40**	**20**
B	**50**	**40**	**50**
C	**80**	**10**	**10**

Candidates generally had some understanding of plotting coordinates. However the actual standard displayed was very poor. Visualisation of the directions in the views for plotting the points was frequently confused.

(i) Draw the front view and top view of the triangle ABC.

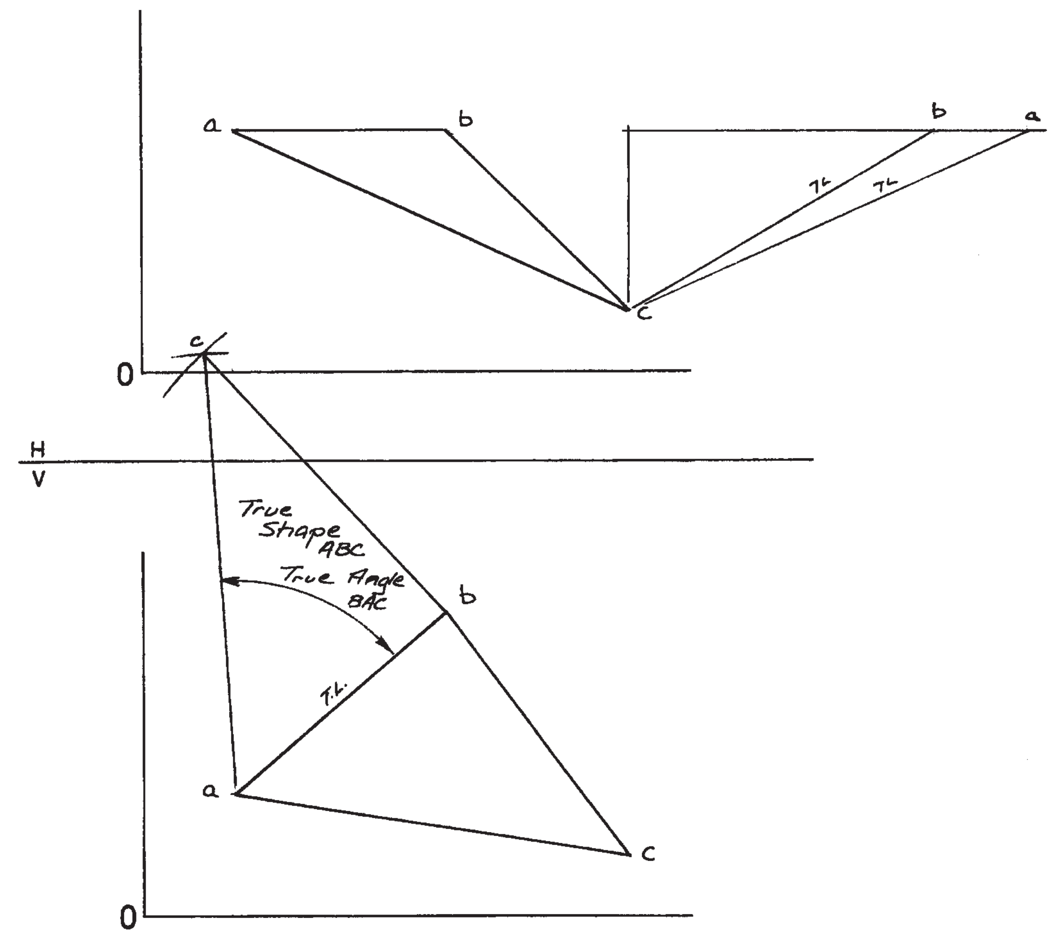
Most of the errors were in confusing the Y and Z directions in the Top and Front Views. This produced triangles that were incorrect, but gained some marks for the angle construction.



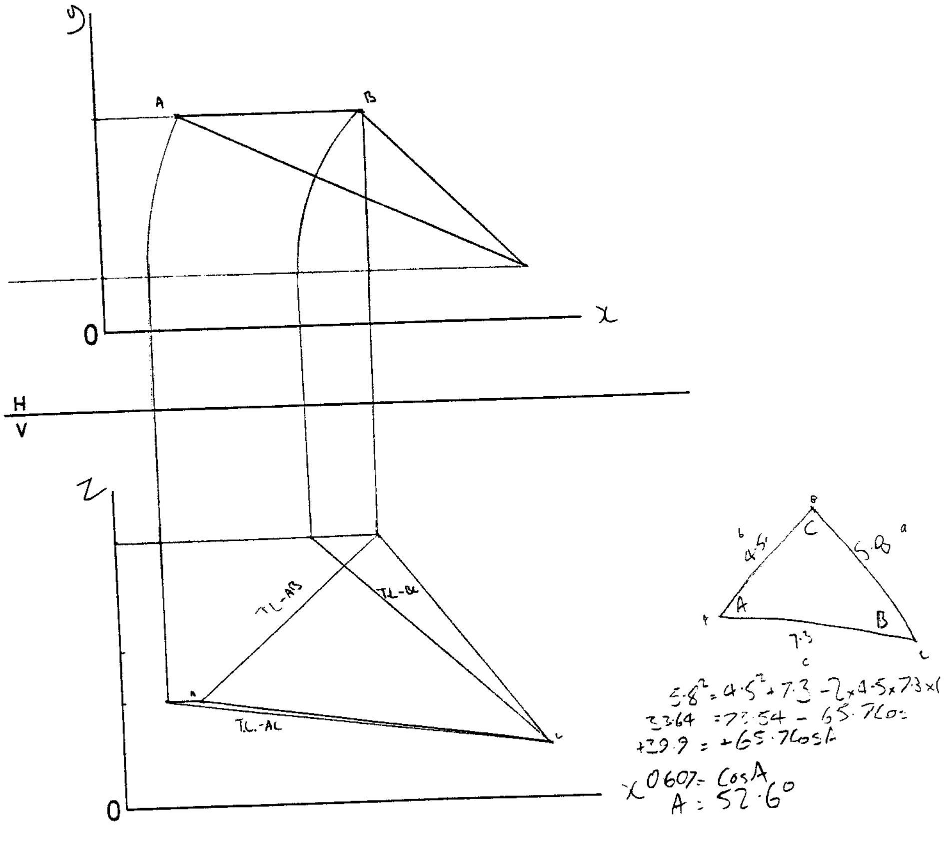
(ii) Determine and state the true angle BAC.

To calculate the true angle, candidates had to first determine true lengths. The sample shown below was a solution with minimal construction lines, and the candidate had recognised that the lengh ‘ab’ was already shown as a true length line in the Front View.

The typical best solution is given below.



An alternative solution, which included a part mathematical solution, shows working and the correct solution. This method is not preferred but was acceptable for full marks. Another common error was made when candidates measured the apparent angle BAC and gave this as the solution, or failed to use any suitable method of construction to find true shape of the triangle to in turn find true angle. Others produced the true shape of the triangle but failed to measure the angle as 52°.



True angle *BAC* = 52.6 °

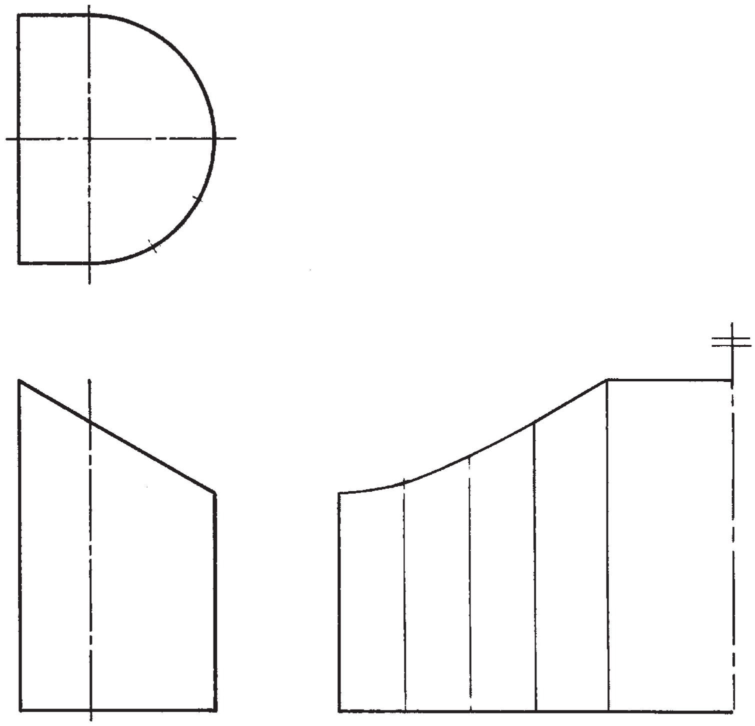
(b) The top view and front view of a downpipe are given below in third-angle projection.

Draw a half-pattern for the downpipe.

This question proved difficult for candidates. It was obvious from the responses that many candidates could not visualise the hollow shape. Some included the true shape of the sloped end of the pipe in their solutions. The problem consists of a collection of basic shapes together with areas that may be triangulated.

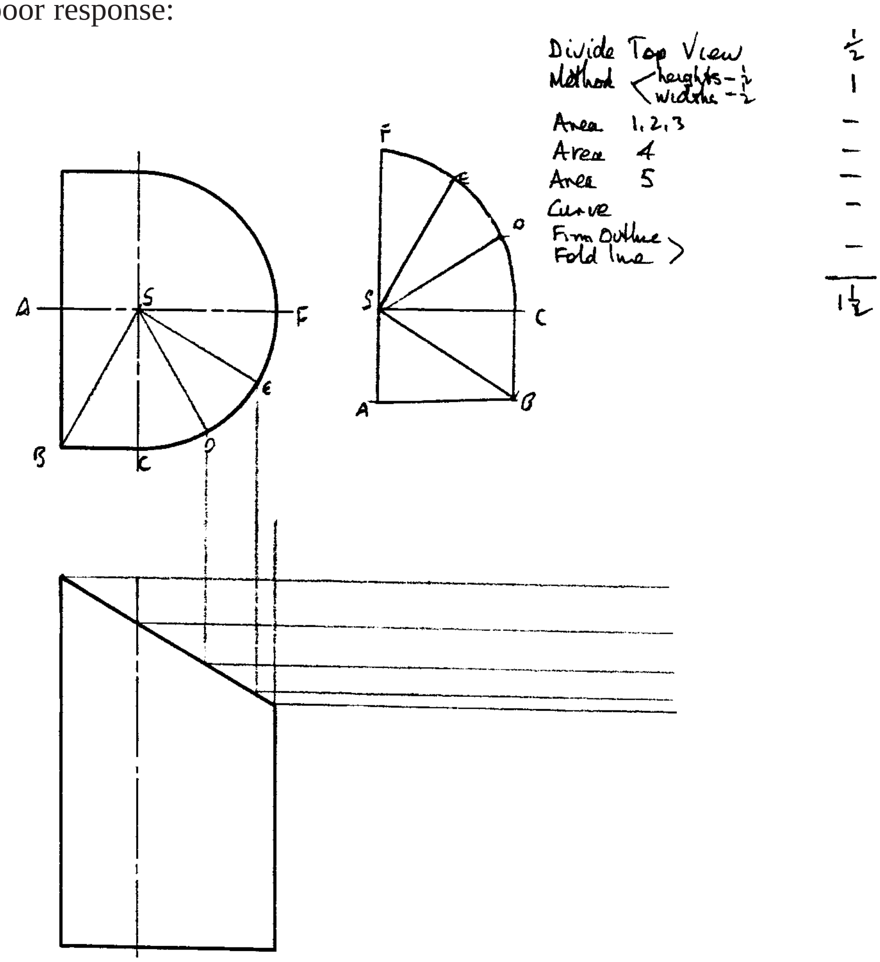
Solutions ranged from finishing on an axis of symmetry, to a thick outline shape.

It was disappointing to see some students divide the quadrant in only two divisions. This caused high inaccuracies in the shape of the cylindrical component of the development.



Candidates need to show some evidence of how they arrive at a graphical solution. This allows for marks to be awarded for a partially correct solution. Construction lines should not be erased, and refer to the front of the paper, where it states ‘set out work clearly, as emphasis will be placed on the working when marks are allocated’.

A typical poor response:



STUDENT NUMBER

CENTRE NUMBER

BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1997
ENGINEERING SCIENCE
2/3 UNIT (COMMON)
SECTION II

(52 Marks)

Total time allowed for Sections I and II—Three hours
(Plus 5 minutes reading time)

DIRECTIONS TO CANDIDATES

- Write your Student Number and Centre Number at the top right-hand corner of this page.
- Allow approximately 90 minutes for this Section.
- Attempt **ALL** questions.
- Answer the questions in the spaces provided in this paper. **Set out your working clearly and neatly. Emphasis will be placed on that working when marks are allocated.**
- All questions are of equal value.
- **Diagrams throughout this paper are to scale, unless otherwise stated.**
- Drawing instruments and Board-approved calculators may be used
- A Formulae Sheet is provided on page 33.
- The Formulae sheet and Rough Work sheet will not be collected.

EXAMINER'S USE ONLY

Question	Max Marks	Marks Awarded	Marks Checked
1	8		
2	8		
3	8		
4	8		
5	8		
6	8		
TOTAL	Max 48		

QUESTION 7

(a) The components listed below were manufactured in 1947 and the manufacturing process used for each is given. State the material used, and give reasons, other than cost, why the manufacturing process was appropriate.

(i) Bicycle frame.

Manufacturing process: brazed lug construction.

Material: *Steel*

Reasons: *Lower temperature of brazing reduces heat effected zone - welding could ruin temper structure of the joined area. Lugs add strength to the joints.*

Many candidates were able to nominate the correct material used for a bicycle frame but failed to describe why the manufacturing process was appropriate. Instead, many chose to describe the properties of the material. This shows the need to read the question carefully rather than assuming what it is asking.

A few candidates chose to nominate the material used in brazing the frame joints as in the example below:

Material: *Brass, mild steel lug*

Reasons: *More surface area, low melting point meant no heat damage to cold worked (work hardened) steel. No annealing needed for heat affected zone.*

(ii) Domestic push-mower handle.

Manufacturing process: cut and shape.

Material: *Timber or Steel*

Reasons: *Easily cut and shaped with the simple tools and processes available in 1947.*

(iii) Brake drum.

Manufacturing process: sand casting.

Material: *Cast iron*

Reasons: *Better strength properties than die casting. Better strength properties than pressing to shape. Most appropriate technology available at the time for casting.*

Candidates answering part (ii) and (iii) gave properties of materials rather than commenting on the reasons for using that process in 1947. They did not remember that they are being tested on their knowledge of the history of technology in the question.

(b) The components listed below were manufactured in 1997, each using different materials. Name each of the materials used.

Component	Material
Racing-bicycle frame	*Kevlar/Carbon fibre Reinforced Polymer Duralumin Chrome Moly Steel Alloy*
Domestic rotary-mower baseplate	*Low carbon steel*
Disk brake callipers for high performance car	*Aluminium alloy*

Most candidates answered correctly in the 1997 time context. Note that the questions asks for a different material to be nominated for each component. Many candidates used the same material more than once. Some candidates nominated 'aluminium' instead of 'aluminium alloy' for disk brake callipers. Clearly, this is inappropriate.

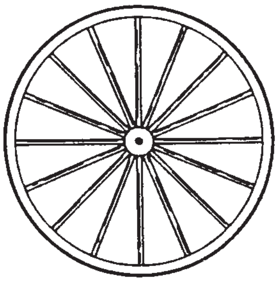
(c) In 1947 asbestos was used in brake lining material. Explain why asbestos is no longer used.

Health concerns involved in production and maintenance have caused its replacement.

Most candidates answered this question well.

(d) For each of the bicycle wheels shown below, explain how the design was influenced by the materials and technology available.

(i)



MACMILLAN 1839

Wrought iron rim on wooden wheel

Availability of wrought iron led to its use as easily produced wear resistant rim.

Spokes are easily shaped, are only loaded in compression.

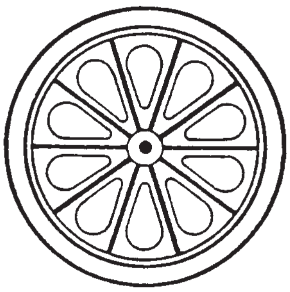
Rim is shrunk-fit to maintain compressive load for durability.

Uses materials and wheelwright technology common to other wheeled vehicles of the day.

Could not be produced in one piece with the technology of the day.

Many answers were possible for this part. The best candidates gave a description of the properties of each material listed then discussed how they contributed to the design, manufacture or use of the bike in 1839. Poor responses were simply a description of the picture or a rewording of the things mentioned already in the caption. Candidates should note that saying *'modern materials (eg polymers) were not discovered yet'* is not a suitable answer.

(ii)



BMX 1980

Vulcanised rubber tyre on a glass-filled, high density polyethylene wheel

Injection moulding of modern polymers enabled lightweight strong designs for the wheel.

Vulcanisation of rubber gives a flexible but durable type suitable for BMX use.

Simplified one piece construction of wheel allows fast production.

Rubber type contributes to traction/rider comfort.

Glass fibres added to give strength, rigidity to wheel.

Candidates were able to relate more easily to this type of wheel and provide better answers. Most candidates commented on the lightweight, strong, impact resistant design of the polyethylene wheel and its suitability for mass production.

When answering question 7: Candidates are encouraged to use correct terminology from the applications component of the course, keeping in mind the historical context of each part of the question.

QUESTION 8

(a) Details of a bicycle are given below. The centre of mass of the bicycle, point D, and the combined centre of mass of the bicycle and rider, point E, are shown on the diagram. The mass of the bicycle is 10 kg.

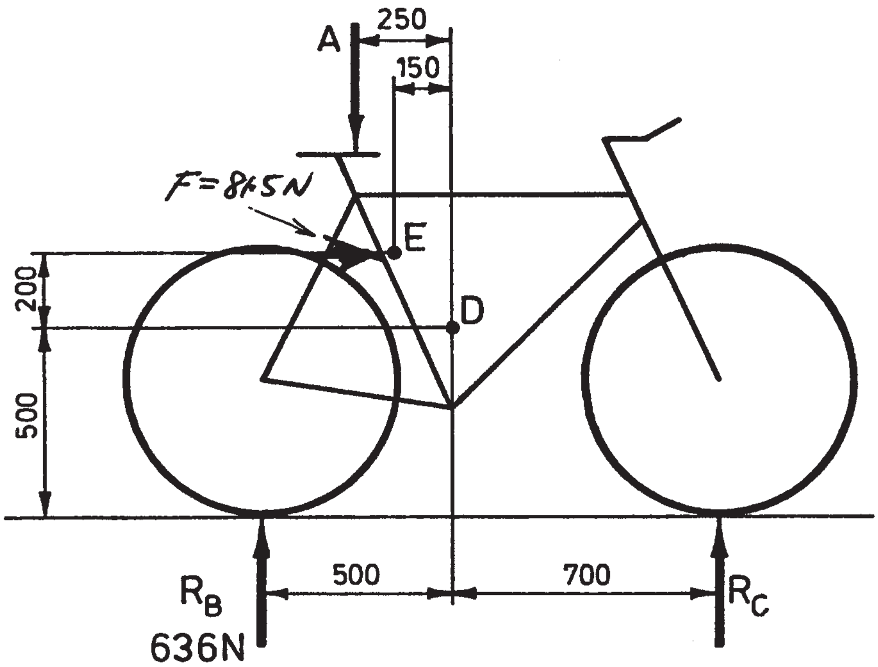
The bicycle accelerates on a level road due to an out-of-balance horizontal force of 81·5 N at point E. During this acceleration the vertical reaction RB, at the rear wheel, is 636 N.

NOTE. Disregard the force on the handlebars and on the pedals.

(i) Determine the vertical downward force of the rider at point A.

(ii) Determine the vertical reaction RC at the front wheel.

$$w_{Bicycle} = mg$$
$$= 10 \text{ x } 9.8$$
$$= 98 \text{ N}$$



Taking moments along ground plane to eliminate one unknown:

$\Sigma M_x = 0$ +

$(636 \text{ x } 1200) + (81.5 \text{ x } 700) - (98 \text{ x } 700) - (A \text{ x } (950) = 0$

$$A = \frac{763200 + 57050 - 68600}{950} = 791N$$

Summing forces vertically:

$\Sigma F_v = 0 \; +\downarrow$

$636 - 791 - 98 + R_c = 0$

$R_c = 253 \text{ N} \uparrow$

or

Taking moments along ground plane to eliminate the second unknown:

$\Sigma M_F = 0 \quad \circlearrowright^{+}$

$(81.5 \times 700) + (636 \times 250) + (98 \times 250) - (R_c \times (950) = 0$

$$\frac{57\ 050 + 159\ 000 + 24\ 500}{950}$$

$R_c = 253\ N\uparrow$

Force at A = 791 N

Reaction R_C = 253N

Candidates often failed to recognise that the 81.5N force acting horizontally at E needed to be considered as part of the system of forces acting on the bike.

Moments equations were often incomplete or taken about an incorrect or inconsistent point.

Many candidates to moments about R_B and therefore, failed to achieve an equation with only one unknown.

Points for candidates:

- Underline key points in question.
- Convert all data to standard or recognised units.
- Ensure that all forces are considered in the answer.
- Apply forces to the diagram in the equation.
- Write moment equations that consider all forces and perpendicular distances.
- Check that the question is answered in the units or form required.
- Carefully analyse the direction of each moment force.
- Use free body diagrams to analyse the question.

This question produced several typical answers. These included;

$\overset{+}{\curvearrowright}\ \Sigma M_C = [636 \times (500 + 700)] - (10 \times 9.8 \times 700) - (A \times 950) + (81.5 \times 700)$

$950\,A = 763200 - 68600 + 57050$

$A = 791.21\,N$

$\Sigma F_v \uparrow + = 636 - 791.2 - 98 + R_c = 0$

$R_c = 253.2\ N$

Force at A = 791.21 N $\downarrow$

Reaction R_C = 253.2 N $\uparrow$

Answers where the 81.5N force was applied towards the rear of the bike.

$M_{RC} = 0$

$M_{RC} = 636 \times 1.2 - 81.5 \times 0.7 - 10 \times 9.8 \times 0.7$

$- A \times 0.950 = 0$

$A = 671.11\ N\ (2\ D.P.)$

$\Sigma V = 0 \uparrow +ve$

$\Sigma V = -671.11 + 636 - 10 \times 9.8 + R_C$

$R_C = 133.11\ N\ (2\ D.P.)$

Force at A = ..671.11.... N

Reaction R_C = ..133.11....... N

Answers where the mass of the bike and rider had been combined at E.

$F = ma$

$81.5 = m \times$

$\Sigma M_{R_C} = 0$

$R_C = 636 \times 1.2 - F_E \times 0.85 + 81.5 \times 0.7$

$= 763.2 - F_E \times 0.85 + 57.05$

$F_E = \frac{820.25}{0.85}$

$= 965\ N$

$\therefore A + D = E$

$A + 98 = 965$

$A = 867$

$\Sigma F_V = 0$

$\therefore = 636 - 867 + 98 + R_C$

Force at A = ...867........ N $\downarrow$

Reaction R_C = ...329........ N $\uparrow$

Each of these solutions were considered correct, with combined masses indicating that the point E was not the typical placement of the combined mass for this situation.

When Mechanics is marked;

'g' can be $10 m/s^2$ or $9.8 m/s^2$.

Incorrect answers 'carried through' are not penalised twice.

No marks are awarded for stating a formula given in the data sheet.

When a correct answer is given with no working, full marks are awarded.

Marks are allocated according to the methods and concepts shown in the solution.

Graphical solutions are given a 5% margin of error.

The units stated in the answer space can be modified, provided the correct units are used.

Angles and measurements can be taken directly from scaled drawings in the question.

(b) A 1·5 m steel cable, with a Young's modulus of 210 GPa, is used in the bicycle braking system. The maximum cable extension is 0·34 mm for a braking force in the cable of 150 N.

Determine the minimum cable diameter required.

$E = 210$ Gpa

$= 210 \times 10^9$ Pa

$$E = \frac{PL}{eA}$$

$$A = \frac{PL}{eE}$$

$$A = \frac{150 \times 1.5}{0.34 \times 10^{-3} \times 210 \times 10^{9}}$$

$$A = 3.15 \times 10^{-6}\ m^2$$

$$A = \frac{\pi d^2}{4} = 3.15 \times 10^{-6} m^2$$

$$A = 3.15\ mm^2$$

$$D = \sqrt{\frac{4 \times 3.15}{\pi}}$$

$$D = 2.00\ mm$$

Diameter ***2.00*** *mm*

The majority of candidates answered this question satisfactorily.

Some candidates had difficulty in manipulating the units within the question successfully.

Candidates who applied the equation E = PL/Ae tended to achieve the solution more readily.

Points for candidates:

Convert all data to standard or recognised units. Show your working, and indicate units.

Conversion of data should allow their consistent application throughout the solution ie m, m^2 and N leads to Pa, while mm, mm^2 and N leads to MPa.

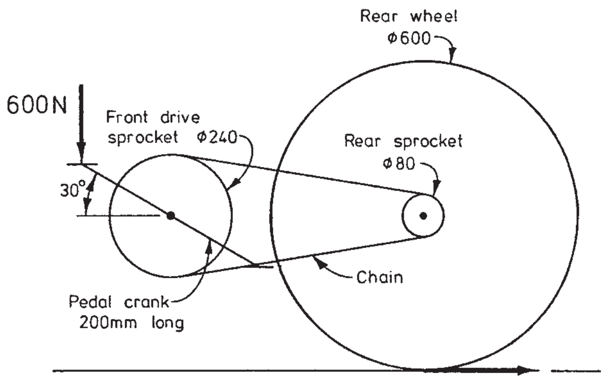
Use of the equation E = Pl/Ae allows for the direct input of data.

Solving equations in stages allows the solution to be easily analysed for marking.

Ensure that the answer is in the form required by the question ie radius or diameter.

QUESTION 9

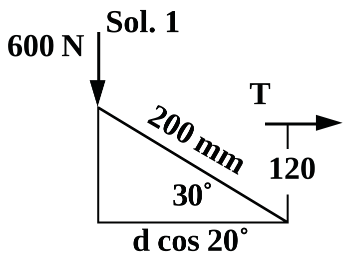
(a) Details of the drive mechanism of a bicycle are given below.



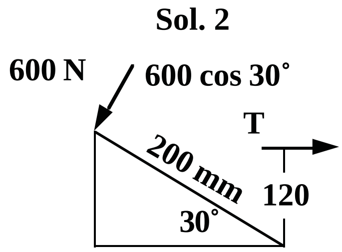
NOT TO SCALE

At a given instant, the pedals are at an angle of 30° to the horizontal, and a vertical force of 600 N is applied to the pedal as shown. Assume 100% efficiency.

(i) Determine the force applied to the chain by the front drive sprocket.



600 x 200 cos 30° = T c 120
T = 866 N



600 cos 30° x 200 = 120T
T = 866 N

Force ***866*** *N*

This question discriminated between candidates, even though it was well answered. The pedal crank distance was often interpreted as 100 mm rather than 200 mm. The inclusion of the efficiency statement may have caused some concern, but it was necessary information, so as not to mislead candidates in their calculations.

(ii) Determine the velocity ratio of the drive mechanism.

Solution. 1

1 Rev. of drive sprocket

Effort moves D = 400

Rear sprocket moves $= \frac{240}{80}$

$= 3$ rev

Load moves 3πD $= 3 \times 600$
$= 1800$

$$VR = \frac{D_E}{D_L} = \frac{400\pi}{1800\pi} = 0.22$$

Solution. 2

Force in chain $\times\, 0.04 =$ *Load* $\times\, 0.3$

$\therefore 866 \times 0.04 =$ *Load* $\times\, 0.3$

Load = 115.47 N

At 100% Efficiency

$$VR = MA = \frac{L}{E} = \frac{115.47}{600 \cos 30°}$$

$$VR = 0.22$$

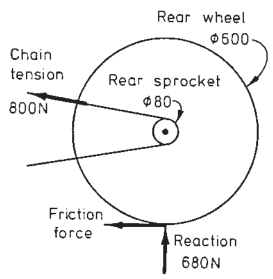
Solution. 3

$$VR = \frac{Driver}{Driven} \times \frac{Driver}{Driven}$$
$$= \frac{200}{120} \times \frac{40}{300}$$
$$= 0.22$$

Velocity ratio ***0.22***

Most candidates who had difficulty, did not include the gear ratios in their calculations. Some candidates calculated the area for both, displaying that they did not understand the concept of Velocity Ratio. More effort is required in this area, as this topic was poorly answered. Three possible methods of solving this problem are given.

(iii) For a different set of conditions, the tension in the chain is 800 N and the vertical reaction at the rear wheel is 680 N. The bicycle is travelling at a constant velocity. Determine the coefficient of friction between the bicycle tyre and the road surface.



NOT TO SCALE

$$F_r \times 300 = 800 \times 40$$
$$F_r = 106.7\ N$$
$$\mu = \frac{F_r}{N}$$
$$= \frac{106.7}{680}$$
$$= 0.157$$

Coefficient of friction 0.16

Candidates had reasonable success with this part. Most realised it was a moment equation solution. Most did not use a free-body diagram to assist in their analysis.

(b) A bicycle is travelling at a constant velocity of 30 km/h against a resistance of 80 N for a distance of 1·5 km.

(i) Determine the work done in travelling a distance of 1·5 km.

$R = 80\ N$
$s = 1.5\ kN$
$= 1500\ m$

$W = Fs$
$= 80 \times 1500$
$= 120\ 000$

Work done 120 kJ

(ii) Determine the power transferred by the cyclist.

Solution. 1

$V = 30\ km/h = 8.33\ m/s$

$P = FV$

$= 80 \text{ x } 8.33$

$= 666.67\ W$

Solution. 2

$W = 120 \times 103$

$t = \frac{1.5}{30} \times 3600$

$P = \frac{W}{t}$

$P = \frac{120 \times 10^3}{\frac{1.5}{30} \times 3600}$

$= 666.67\ W$

Solution. 3

$F = 80$

$s = 1500$

$t = \frac{1.5}{30} \times 3600$

$P = \frac{80 \times 1500}{\frac{1.5}{30} \times 3600}$

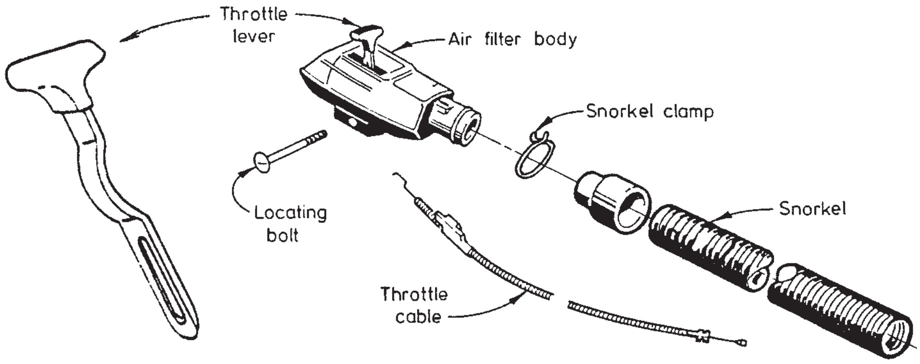
$= 666.67\ W$

Power 666.67 W

Candidates scored well in this section. The concepts and substitutions were understood, and a variety of solutions were presented.

QUESTION 10

A pictorial drawing of a lawnmower air filter system is shown below.



(a) The air filter body is made from high-density polyethylene.

(i) Name a suitable manufacturing process for the air filter body.

Injection Moulding

Because of the construction of the air filter body and the nature of the material, the only acceptable answer was injection moulding.

(ii) The throttle cable cover is manufactured by extrusion.

Describe the extrusion process.

Heated material is forced through a die to produce the required shape.

There was quite a lot of confusion between the process of extrusion and drawing. Candidates often indicated that the material was being pulled through a die (indicating drawing) rather than being forced/pushed through a die as in extrusion. A piece of metal is **heated** and **forced through a die**, the die being the shape of the finished product.

(iii) The throttle lever is made from cold rolled 0·2% carbon steel. Name a manufacturing process that may be used to form the curved section, and a manufacturing process used to form the elongated hole.

Curved section *Pressing/Cold bending*

Candidate responses to this question varied. Most understood the need to use a compressive force to shape the part. The low carbon content of the steel would not require a 'hot' forming process. Cold forming would increase further the strength and rigidity of the lever.

Elongated hole *Punching/Piercing*

This portion of the question was only successfully answered by 50% of the candidates. The majority either repeated an answer given (ie forging) or chose to use a procedure involving drilling and then sawing the hole.

Most candidates failed to recognise that the method should have been a one step process involving shearing.

(iv) State a manufacturing property and a service property for the components in the table below.

Component	*Materials*	*Manufacturing property*	*Service property*
Throttle lever	**0·2% carbon steel**	*Malleability*	*Stiffness/ Bending strength*
Snorkel clamp	**0·5% carbon steel**	*Ductility*	*Stiffness/ Resilience*
Snorkel	**Low-density polyethylene**	*Plasticity*	*Flexibility/ uv stability*

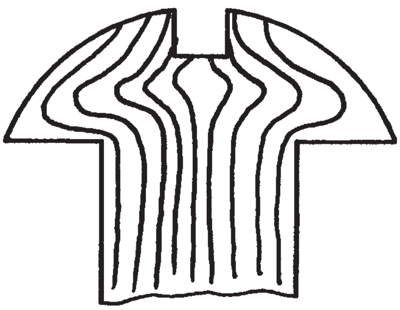
Extremely poorly answered by the majority of candidates. Most failed to identify a manufacturing property (one property which the material possesses to enable it to be used to produce the desired product) ie 0.2%C steel has to be ductile/malleable enough to be cold formed.

A property is usually a technical term, not a description of what happens, eg ‘so the lever can work properly’, or ‘so the handle can fold down’.

The same applied for service properties (a property required of the product when in use) ie the snorkel needs to be flexible and resilient in order for it to bend without collapsing. The sample above indicates the preferred, better responses.

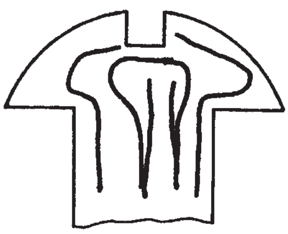
(b) The locating bolt is made from 0·35% carbon steel. The head is hot formed by upsetting. The slot is machined at a later stage.

(i) Sketch the grainflow of the finished bolt.

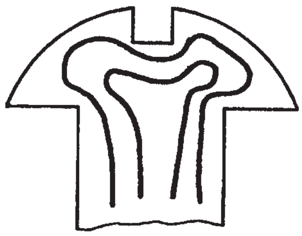


Candidates indicated that they were familiar with the concept of grainflow (they demonstrated that the grains flowed around the head of the bolt) and the notion that the slot had been machined.

Both grain flow diagrams below are incorrect



Indicates flow lines proceed fully around head of bolt.



Example indicates the slot to be stamped.

Grain flow or fibre is the alignment of impurities that results due to the flow of material under the shaping or forming forces. It appears in both hot and cold worked metals. It is more pronounced in cold worked metal as the grains also flow and become aligned. Hot worked metals, may result in equiaxial grains, but the impurities will still show the fibre structure. This structure is typically viewed as a macrostructure, and is easily produced through long term etching.

(ii) The bolt has been coated to prevent corrosion. Name a suitable metal used to coat the bolt.

Zinc

Extremely well answered question with a variety of correct and thoughtful responses.

(iii) State ONE advantage of forming a screw thread by cold rolling.

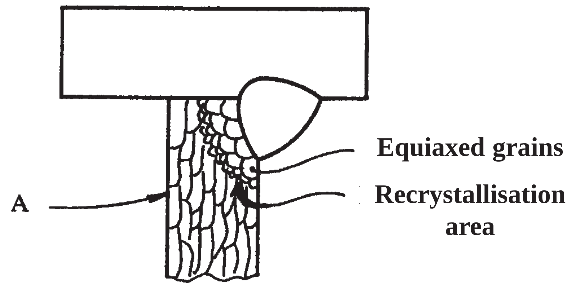
Increased tensile stress/work hardened

Candidates answered this section quite well, understanding that rolling produced some degree of grainflow, imparting strength into the thread.

Some candidates answered correctly, interpreting manufacturing techniques being advantaged.

(c) The top portion of the throttle lever is welded on one side using a single run weld. A sectioned view of part of the welded lever is shown below.

Draw and label the resultant grain structure of the parent metal of part A.



Heat affected zone clearly shown as being different to the parent metal.

Well answered by the majority of candidates. Most recognised that there would be some change occurring around the weld site. Common errors were confined to the 'heat affected zone'.

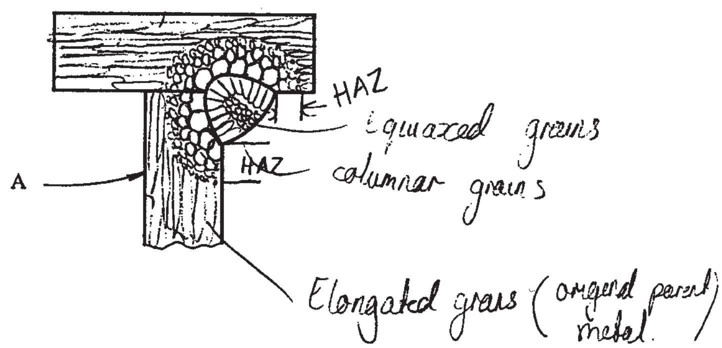
These included:

- The addition of columnar grains
- The omission of smaller recrystallised grains which occur close to the parent metal.
- The reversal of larger equi-axed grains (close to the weld) and recrystallised grains (close to the parent metal).

The grains are larger closer to the weld, the source of heat. The grains in this region recrystallise and grow to be larger, compared to those further away from the heat source. There comes a point where the parent metal is not affected by the heat, and this becomes the limit of the heat affected zone (H.A.Z.). This line is marked by an area of small recrystallised grains.

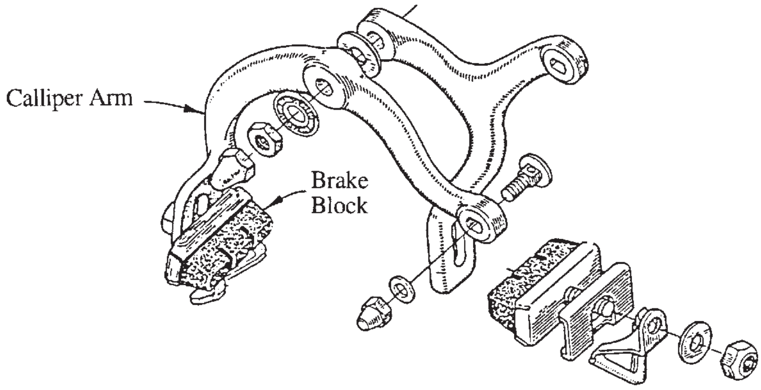
Some other errors were related to misinterpreting the question resulting in the weld structure being identified.

A typical good response is given below.



QUESTION 11

The drawing below shows parts of a bicycle side-pull brake calliper.



(a) The brake block is a composite material. It is composed of neoprene rubber, 10% glass fibre, and carbon black. The neoprene is 10% vulcanised with sulfur.

(i) Briefly explain the mechanism of vulcanisation.

The addition of sulfur causes strong covalent crosslinking between the polymer chains.

Generally the knowledge that vulcanisation was a crosslinking process was well understood by the candidates. The majority answered with a brief statement indicating that vulcanisation caused crosslinking.

A few candidates indicated that double bonds in the polymer chains were broken with the addition of sulphur thus causing crosslinking between polymers.

Sample answer:

Vulcanisation is the process of crosslinking in which sulphur atoms form covalent bonds between polymer chains, increasing strength.

(ii) The batched material is formed and cured using compression moulding. Briefly describe this process.

The material is placed into a mould where it is subject to heat and pressure for a period of time.

Compression moulding was not identified by most candidates. It was evident that many confused it with other plastic or metal processes, particularly injection moulding.

Candidates did not process the knowledge that compression moulding required the resin material to be placed in the mould in a solid state then heated and pressurised to cause curing.

Many candidates used inappropriate terminology related to metals. (They failed to link terms such as **cured** to thermo-setting polymers).

Batched polymer is placed in a permanent metal mould. Mould shuts and heat is applied, along with pressure, to the mould. The mould opens after curing has occurred and the object is ejected.

(iii) For each of the materials listed, write one specific service property that the material contributes to the composite material in the brake block.

Neoprene rubber: *Frictional properties or Resilience*

Carbon black: *UV Stable or Increased Strength or Wear Resistance*

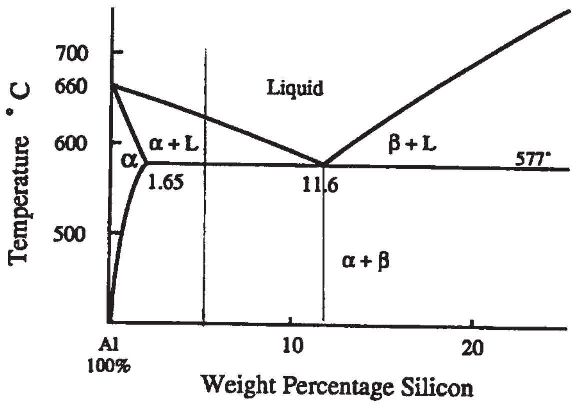
Glass fibre: *Dimensional Stability or Shear Strength*

Sulfur: *Hardness or Rigidity*

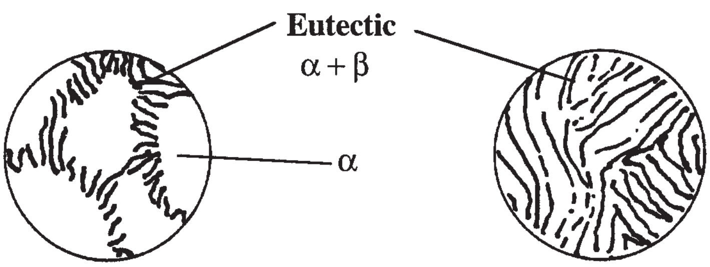
Candidates exhibited confusion in relating service properties (ie properties that the material requires to be used in the given function to the materials mentioned. For example, how did the glass fibre help the brake block function).

Apart from learning properties of individual materials, some mention should be made of their effect on composites. For example neoprene on its own is a flexible elastomer but the addition of carbon black improves the wear resistance of the brake block.

(b) A portion of the aluminium–silicon phase equilibrium diagram is given below.



(i) Two alloys, a 95% aluminium–5% silicon alloy, and an 88·4% aluminium–11·6% silicon alloy, are cooled under equilibrium conditions to room temperature. Draw and label the resultant microstructure for each of the alloys.



95% ALUMINIUM–5% SILICON   88·4% ALUMINIUM–11·6% SILICON

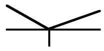
The interpretation and translation of the phase diagram to micro structure encountered the following problems:

a) Definition of the actual size.

b) Confusing α and β with Al and Si.

c) Mixing terms reserved for the iron-iron carbide phase diagram.

Candidates should concentrate on several basic rules with this type of diagram;

Firstly that the micro structure at the eutectic  will normally be a lamellar structure, eg finger print pattern and will contain both α and β phases (plates).

Secondly if an alloy is to the left of the eutectic composition it will contain more of the α phase.

Thirdly if the composition of the alloy is to the right of the eutectic then it will have more of the β phase.

When sketching micro structures candidates are advised to make them large, showing up to 10 grains and label the areas as the question stipulates.

(ii) Explain, in terms of the microstructures, why the 5% silicon alloy is softer and more ductile than the 11·6% silicon alloy.

The 5% silicon alloy contains larger areas of α phase which is often softer and more ductile than the eutectic phase.

This question was frequently answered without reference to the given phase diagram and the regions within. Common errors involved answering in terms of the two alloying elements ie indicating that it was soft and therefore an alloy which has more Al would be softer. For example, Al is much more softer and ductile than silicon.

Candidates need to recognise that the phases α and β have distinct properties and that the α phase is always softer than the β phase. Also that as you move to the left of the eutectic more α phase will appear.

The presence of equiaxed α grains increases the alloys softness and ductility. The eutectic mix is a harder more brittle phase than the 'α' which is soft and ductile.

(iii) A die-cast aluminium alloy, containing 5% silicon, is used to manufacture the calliper arms. Describe the die-cast process.

Molten metal is forced into the mould and allowed to solidify.

This question was answered quite well by the candidates. Generally all candidates recognised the fact that the alloy had to be molten in order to cast it.

Common errors involved descriptions of sand casting and the lack of some form of pressure being applied in the process.

The heated metal is poured into a suitable mould and is allowed to solidify.

Candidates should be encouraged to summarise all forming processes, breaking them down into their key functions or steps eg for die-casting:

Molten metal is forced under pressure into a permanent metal die and allowed to solidify and then ejected.

QUESTION 12

This question examines aspects and disciplines in Engineering Drawing including:

interpreting and reading pictorial representation of engineered components;
assembly drawing;
detail drawing;
sectioning of components;
dimensioning;
application of AS1100 drawing standards.

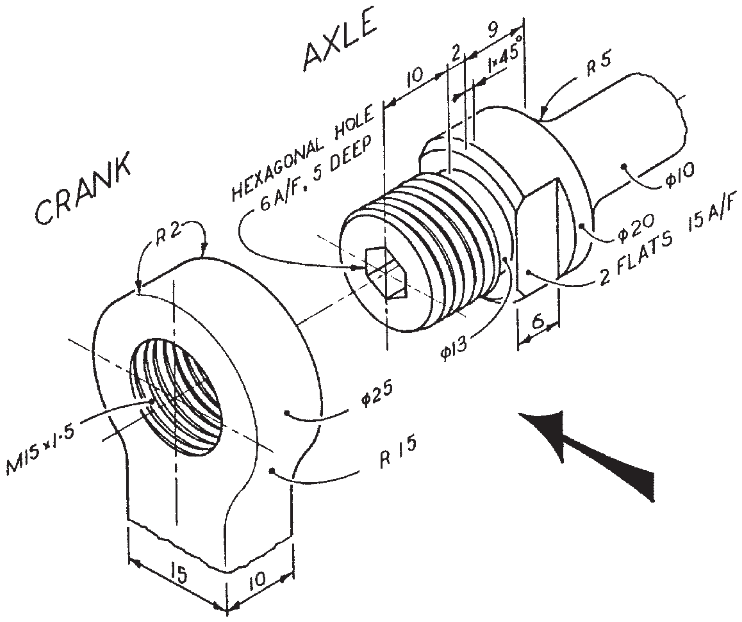
The mean was at half marks for this question, with very few candidates receiving full marks or zero.

Shape and size details of part of a bicycle pedal crank and part of an axle are given in the exploded pictorial drawing.

(a) Using a scale of 2:1, complete the left-side view of the assembled crank and axle. Do NOT show hidden outline.

(b) Project a part-sectional front view of the assembled crank and axle, when viewed in the direction of the arrow.

- **The crank is to be part-sectioned to show the axle as visible outline.**
- **The axle is also to be part-sectioned to show the hexagonal hole as visible outline.**



The marking scale is designed to objectively and consistently recognise and reward all correct responses made by the candidates. In designing the marking scale, the solution is broken into individual components or features and these are then examined for:

representation of the shape concept;
size;
relationship with other features;
representation according to AS1100 standards.

As an example, a shaft of 50 mm length and 10 mm diameter could be broken down into the following four responses.

Shaft — drawing the item Shape — lines, diameter, length, break shape.
✓ ✓ ✓ ✓ ✓

All components are treated in this manner by allocating a tick to each aspect of the component. This system allows markers to allocate ticks to every step which is taken as a candidate completes a response to the question.

Once the ticks for each component are totalled, a conversion scale is used to convert the number of ticks to a final mark.

The conversion process allows candidates to achieve full marks even when their solution has a small degree of error. See figure below.

An example of this type of marking scale is given below.

Question 12 Section II — MARKING SCALE Mk II, 21.11.97

• LSV	Shape, Ø15, thick	✓✓✓		
	Shape, Ø13.5, thin	✓✓✓		
	Shape, 6AF	✓✓		8
• FV AxleThread.End	Shape, proj 15, L10	✓✓✓		
	Shape, 45°, thread shape, proj 13.5	✓✓✓✓		7
• HexagonalHole	Shape, proj 6AF, shape, 5 deep	✓✓✓✓		
• Groove	Shape, Ø13, L2	✓✓✓		7
• Part Section/s	Part section concept	✓		
	Hatching axle, hatching crank	✓✓		
	Hatching crank thread, differentiation, thin	✓✓✓		6
• Crank	Shape, proj Ø25, T10, assembled	✓✓✓✓		
• Fillet	Shape, R2	✓✓		
• Unengaged thread	Thick/thin	✓		7
• Flange	Shape, Ø20, T9	✓✓✓		
• Chamfer	Shape, edge	✓✓		
• Flat	Shape, 15AF, L6, chamfer shape, diagonal	✓✓✓✓✓		10
• Shaft	Shape, Ø10, break shape	✓✓✓		
• Fillet	Shape, R5	✓✓		5
		TOTAL		50

0	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24	25-26	27-28	29-30	31-32	33-34	35-36	37-38	39-40	41-42	43-44	45-46	47-50
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

The candidates' responses to this question indicated a good general knowledge of assembly drawing, however some areas of the question were poorly answered. These are discussed below.

The most common error made by the candidates was failure to completely assemble the crank onto the axle. If the crank was not assembled hard against the flange, there was no reason for indicating the unengaged thread on the crank (see 'a' on figure 1) or the thread exposed outside the crank. (see 'b' on figure 1)

In failing to assemble the parts correctly the candidates lost the opportunity to gain marks allocated for these areas.

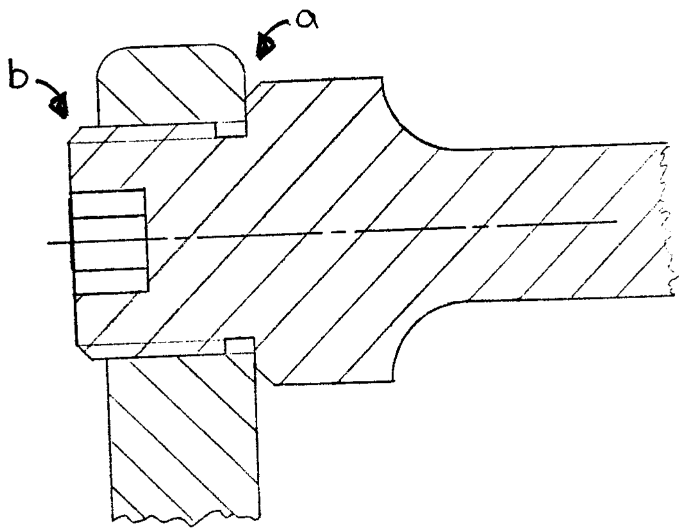


Figure 1 - Incorrect Fully Sectioned Response

Another area of the question which was poorly answered was the candidates' lack of understanding and therefore inability to part section. Many candidates included half and full sections in their responses. This meant that external features like the 15 AF were not shown and therefore marks could not be awarded for these features. (See figure 1)

Many candidates correctly part-sectioned the crank and then incorrectly part-sectioned the end of the axle (See figure 2). This example also shows the incorrect position of the crank mentioned previously.

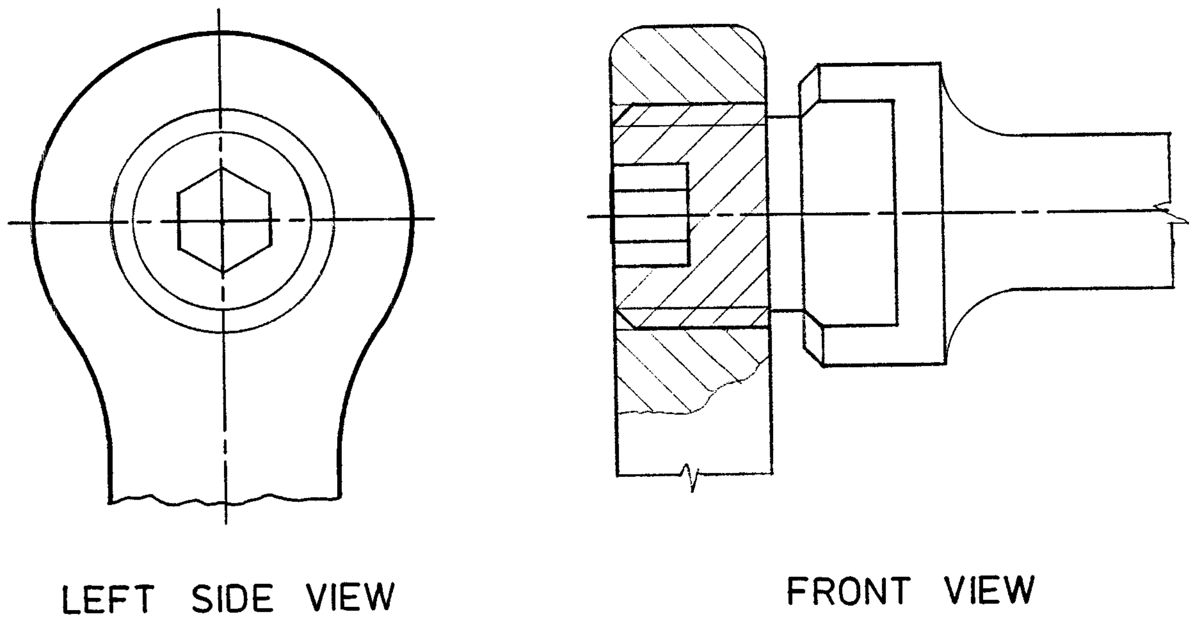


Figure 2

Candidates' understanding of the standards examined in this question was generally poor. Areas of concern include:

Engaged thread in the left side view in Figure 3 over the page. Candidates unable to interpret the thread data ie M15 × 1.5 given in the question.

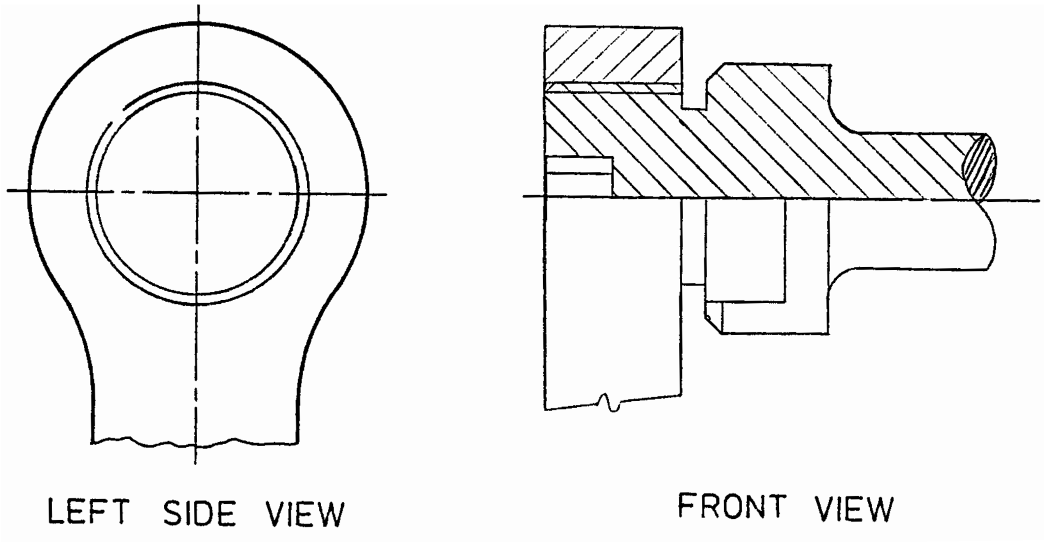


Figure 3

In this example, the line indicating the root diameter of the thread, should be ϕ 13.5, thin and broken, inside the outline which should be ϕ 15. See correct solution below.

Standards:

Standards used to represent breaks. The crank should be finished with a thin black freehand line (figure 1). The shaft should be 'figure 8' not freehand or long break (figure 2).

Standards used to represent flats. The thin black diagonals (figure 4) shown on the crank, indicate a flat surface.

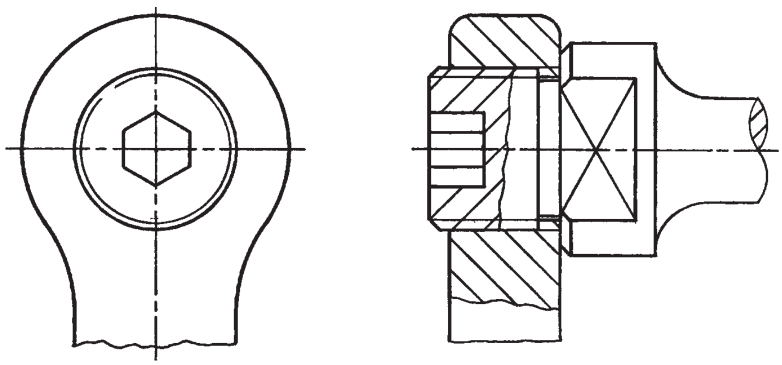
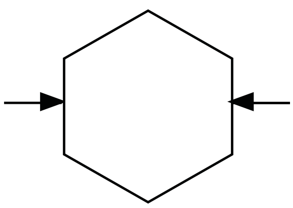


Figure 4 — The correct response

Standards used for hatching. This was generally answered well, however, some candidates still include too many lines too close together, wasting valuable examination time. See figure 6.

Some candidates lacked understanding of the standard 'AF' (across the flats). This is the measurement between the flats that determines the size of the spanner required to hold, in this case, the shaft.



Many candidates lacked knowledge of method of construction of the hexagon required to be drawn in the left side view, from which the width of the flats could be projected to the front view (see Figure 5 over page).

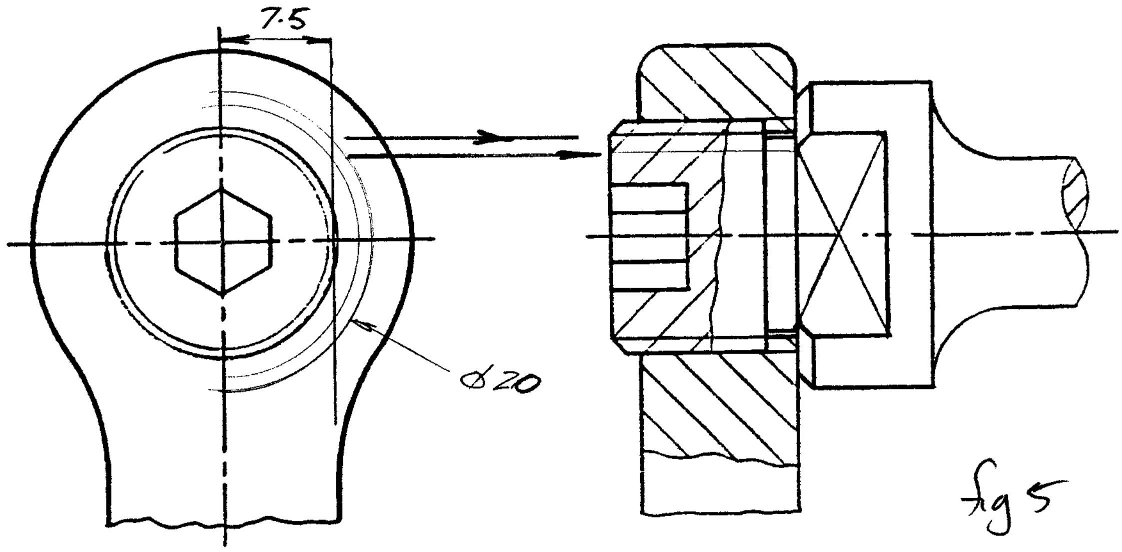
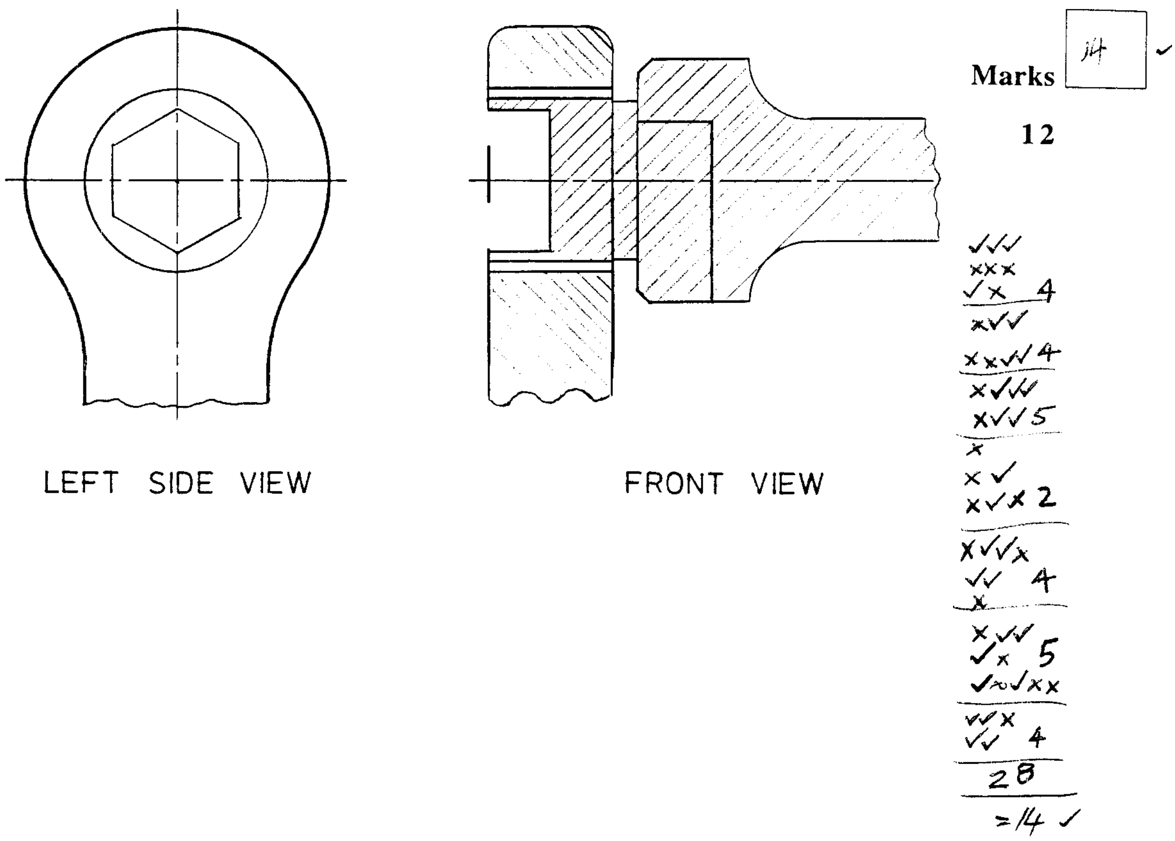


Figure 5

Many candidates displayed poor understanding in interpreting a pictorial drawing and then representing it in orthogonal projection. This was made evident by the number of responses with the flat incorrectly positioned on the shaft. See figure 6 below, which is a good example of this type of misunderstanding.

Figure 6



Student Number

Centre Number

BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1997
ENGINEERING SCIENCE
3 UNIT (COMMON)
SECTION I

(50 Marks)

Total time allowed—One hour and a half
(Plus 5 minutes reading time)

DIRECTIONS TO CANDIDATES

- Write your Student Number and Centre Number at the top right-hand corner of this page.
- Attempt EIGHT questions.
- **Section I** (20 marks) Attempt BOTH questions.
  Section II (15 marks) Attempt THREE questions.
  Section III (15 marks) Attempt THREE questions.
- All questions in Sections II and III are of equal value.
- Answer the questions in the spaces provided in this paper.
- **Set out your working clearly and neatly. Emphasis will be placed on that working when marks are allocated.**
- All questions are of equal value.
- Diagrams throughout this paper are to scale, unless otherwise stated.
- Drawing instruments and Board-approved calculators may be used
- A Formulae Sheet is provided on page 21–2.
- The Formulae sheet will not be collected.

EXAMINER'S USE ONLY

Question	Max Marks	Marks Awarded	Marks Checked
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
TOTAL	Max 50		

QUESTION 1

This question tested concepts of circular motion. Candidates had to be able to manipulate the basic equations of circular motion, to convert units of revolutions to radians and understand the difference between linear and angular motion of a point. A significant number of candidates had problems in all these areas.

(a) A 1 metre diameter flywheel accelerates uniformly from 10 r.p.m. to 2000 r.p.m. in 5 seconds.

(i) Determine the angular acceleration.

$$\begin{array}{llll} d = 1\ m & \omega_o = 10\ rpm & t & = 5\ sec \\ & = 10 \times \dfrac{2\pi}{60} = 1.047\ rad/s & \omega & = \omega_o + \alpha t \\ \omega = 2000\ rpm & & 209.4 & = 1.047 + \alpha \ x\ 5 \\ & = 2000 \times \dfrac{2\pi}{60} = 209.4\ rad/s & \alpha & = 41.7\ rad/s \end{array}$$

Angular acceleration **41.7** *rad/s*^{2}

The majority of candidates were able to answer this part correctly. Some used the equation in the format:

$a = \dfrac{w - w_o}{t}$ and included the conversion of units in one step:

$$a = \left(2000 \cdot \frac{2p}{60} - 10 \cdot \frac{2p}{60}\right) \cdot \frac{1}{5} = 41.7 \ \ rad / s^2$$

(ii) Determine how many revolutions the flywheel makes in attaining its speed of 2000 r.p.m.

$$\theta = \left(\frac{\omega_o + \omega}{2}\right) t \qquad = \left(\frac{10 + 2000}{2}\right) \times \frac{5}{60}$$

$$= 83.75 \ \ rev$$

Revolutions **84** *revs*

This part required an understanding of the relationship between ω, θ and time. For a constant acceleration the average angular velocity can be used to calculate angular displacement. If ω is kept in r.p.m. units, then time must be minutes.

Candidates preferred to use $q = w_o t + \frac{1}{2} a t^2$ Since the α had already been calculated in rad/sec^2 , the units of θ will be in radians which needs to be converted back to revolutions.

$$q = w_o t + \tfrac{1}{2} a t^2$$

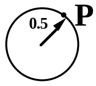
$$= 10 \cdot \frac{2p}{60} \cdot 5 + \frac{1}{2} \cdot 41.7 \cdot 5^2$$

$= 526.2$ *radians*

$= 83.75$ *r.p.m.*

(iii) Consider a point on the rim of the flywheel 0·25 seconds after the flywheel began accelerating from 10 r.p.m.

1. Determine the linear velocity of the point.



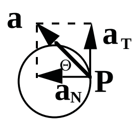
$t = 0.25$ *sec*
$\omega_o = 1.047$ *rad/s*
$\alpha = 41.7$ *rad/s*
$\omega = ?$

$\omega = \omega_o + \alpha t$
$= 1.047 + 41.7 \times 0.25$
$\alpha = 11.47$ *rad/s*
$v = r\omega$
$= 0.5 \times 11.47 = 5.7$ *m/s*

Linear velocity 5.7 *m/s*

This part required the candidates to understand and be able to calculate linear velocity, knowing ω and distance from the centre. Most candidates could calculate v. Many used the angular velocity of 10 r.p.m. instead of calculating the actual at **t=0.25 secs**. The value for radians was often mistaken for 500 mm as in the first part of the question.

2. Determine both the magnitude and the direction of the resultant linear acceleration of the point. Consider both the tangential and normal accelerations.



$a_T = r\alpha$
$v = 0.5 \times 41.7$
$= 20.85\ m/s^2$
$a_N = r\omega^2$
$= 0.5 \times 11.47$
$= 65.78\ m/s^2$

$\tan\theta = \dfrac{20.85}{65.78}$
$= 17.6^\circ$
$\sin\theta = \dfrac{20.85}{a}$
$\sin\theta = 69\ m/s^2$

Linear acceleration **69** m/s^2
Angle to the normal **17.6°**

This was a difficult question. Most candidates were able to use the relationship **$a_r = ra$** to find the tangential acceleration, but did not find a_N. An alternative approach used by many was:

$$a = \frac{v^2}{r} = \frac{5.74^2}{\frac{1}{2}} = 65.9\ ms^{-2}$$

$$a_T = ra = \frac{1}{2} \cdot 417 = 20.89\ ms^{-2}$$

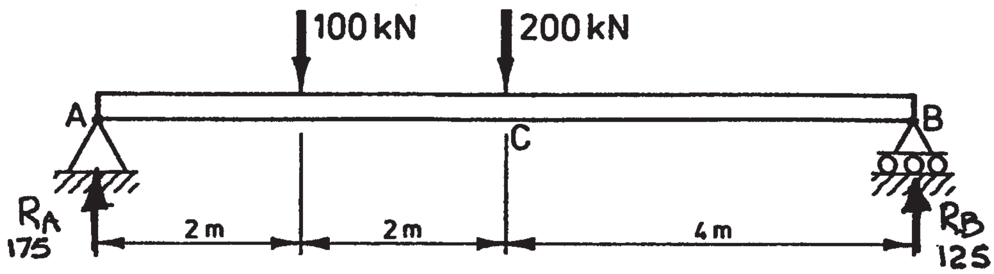
$$a = \sqrt{6.59^2 + 20.89^2} = 69.1\ ms^{-2}$$

$$\tan q = \frac{20.85}{65.9}$$

$q =$ **17°33’**

A revision of the concept of vectors would be helpful before starting this area of circular motion.

(b) A laminated beam 250 mm wide, 500 mm deep, and 8 m long is simply supported at A and at B as shown below. Neglect the mass of the beam.



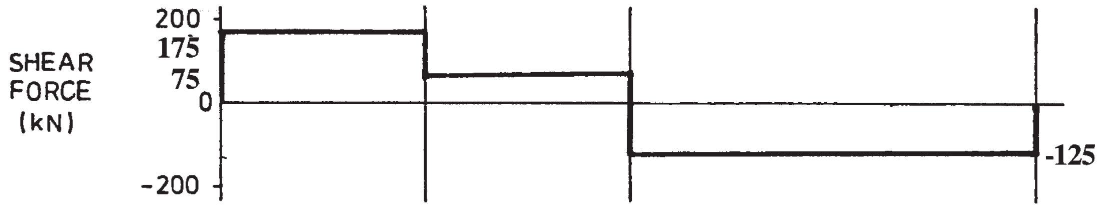
(i) Calculate the reactions at A and at B.

$$\Sigma M_A: \quad 100 \times 2 + 200 \times 4 - R_B \times 8 = 0$$
$$R_B = 125\ kN \uparrow$$
$$\Sigma M_B: \quad 200 \times 4 + 100 \times 6 - R_A \times 8 = 0$$
$$R_A = 175\ kN \uparrow$$

Reaction at A ***175*** *kN*
Reaction at B ***125*** *kN*

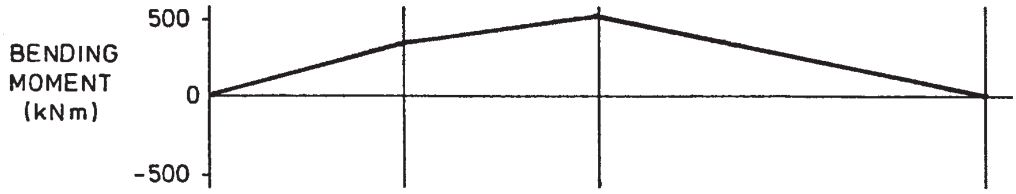
This part of the question is always well answered, and is necessary for use in the following parts.

(ii) Draw the shear force diagram for the beam.



Most candidates have a good understanding of shear force. Some candidates used different conventions for – without penalty.

(iii) Draw the bending moment diagram for the beam.



$$\Sigma M_1 = 175 \times 2 = 350\ kNm \qquad \Sigma M_2 = 125 \times 4 = 500\ kNm$$

Most candidates recognised that a simply supported beam has zero bending moments at each end, and were able to take a moment equation at the points of loading to find the value of the moment. Most plotted the BM as a straight line, as only point loads were being applied. Many did not show the correct sign of BM (+ve) even though this is critical to BM calculations.

eg $BM = 0$ on LHS

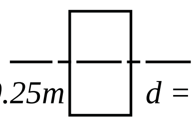
$BM = 0$ on RHS

At C: $(-175 \times 4) + (100 \times 2) + BM = 0 \qquad BM = +500\ kNm$

At 100 kN: $(-175 \times 2) + BM = 0 \qquad BM = +350\ kNm$

(iv) Determine the maximum bending stress at point C.

$b = 0.25\ m$



$y = 0.25m$ $\quad d = 0.5\ m$

$$I = \frac{bd^3}{12} = \frac{0.25 \times 0.5^3}{12} = 2.6 \times 10^{-3}$$

$$\sigma = \frac{My}{I} = \frac{500 \times 10^3 \times 0.25}{2.6 \times 10^{-3}} = 48 \times 10^6\ Pa$$

Bending stress ***48*** *MPa*

Most candidates lost marks in the calculation of 'I' or in the use of consistent use of units in the stress equation. A large percentage of candidates confused Bending Stress with Axial Stress calculations, and failed to use 250 mm as the value of 'y' for maximum stress (maximum distance from neutral axis).

Some candidates preferred to convert the BM at C to 500 $\times$ 10^6 kNmm, and use the dimensions of the beam in millimetres as consistent units.

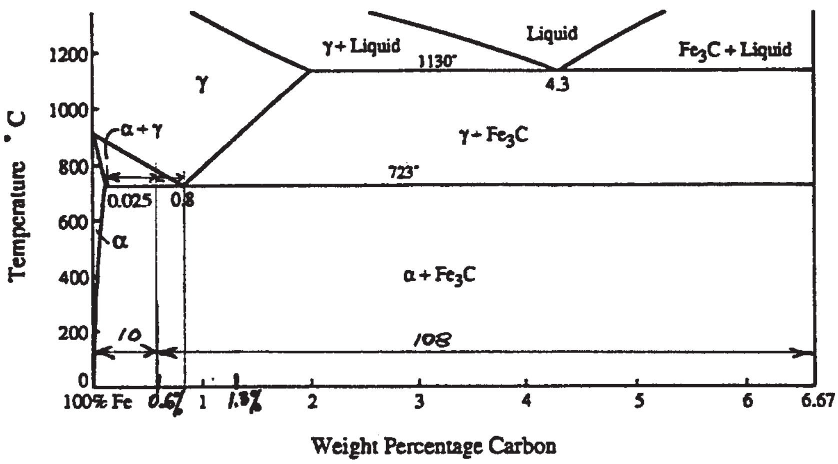
At c:

$$0 = -175 \times 4$$
$$= 50 \text{ kNm}$$
$$I = \frac{250 \cdot 500^3}{12}$$

$$S = \frac{My}{I}$$
$$= \frac{500 \cdot 10^3 \cdot 10^3 \cdot 250}{2.6 \cdot 10^9}$$
$$= 48 \text{ Mpa}$$

QUESTION 2

(a) A portion of the iron–carbon phase diagram is given below. A 0·6% carbon steel is cooled under equilibrium conditions to room temperature.



(i) Determine the relative amounts of ferrite and cementite at room temperature.

Candidates need to be clear about distinguishing between the relative amounts of the microconstituents (ferrite and cementite) as compared to the relative amounts of the phases present (ferrite and perlite). Many candidates are unable to accurately apply the Lever Rule.

Relative amount of Ferrite $= \dfrac{6.67 - 0.6}{6.67} \times \dfrac{100}{1} = 91\%$

Relative amount of Cementite $= \dfrac{0.6 - 0}{6.67} \times \dfrac{100}{1} = 9\%$

Relative amount of ferrite 91%

Relative amount of cementite 9%

This section deals with the interpretation of information from a portion of the iron–carbon phase diagram.

Candidates should recognise and draw in :

(a) A vertical composition line at 0.6% carbon.

(b) A horizontal temperature line at room temperature.

(c) Apply the principle of the lever rule.

relative amount of ferrite $= \dfrac{YZ}{XZ} \cdot \dfrac{100}{1}$

relative amount of pearlite $= \dfrac{YX}{XZ} \cdot \dfrac{100}{1}$

Note: the lengths of the lever arms can be obtained by using the percentages obtained by dropping vertical lines down to the composition scale OR alternatively you can measure the lengths of the lever arms using a rule.

(ii) Determine the relative amount of pearlite at room temperature.

Relatively well answered showing that candidates are more acquainted with applying the Lever Rule to determine the relative amounts of phases present.

Relative amount of Pearlite $\dfrac{0.6 - 0}{0.8} \times \dfrac{100}{1} = 75\%$

Relative amount of pearlite ***75%***

Candidates should recognise that a eutectoid exits at = 0.8%C — a eutectoid consists of 100% pearlite therefore by ratios

.2%C = 25% pearlite

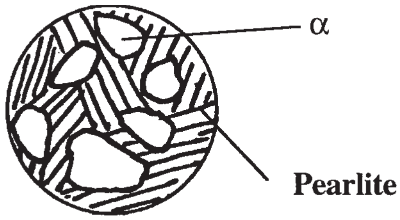
.4%C = 50% pearlite

.6%C = 75% pearlite

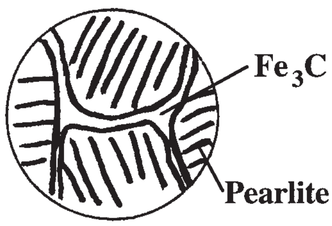
ALTERNATIVELY you can apply the principles of the lever rule.

(iii) A 0·6% carbon steel and a 1·3% carbon steel are cooled under equilibrium conditions to room temperature.

1. Draw and label the resultant microstructure for each steel.



0·6% CARBON STEEL



1·3% CARBON STEEL

Well answered although there is a wide discrepancy in candidates' ability to accurately represent microstructures. For the 1.3%C steel in particular, a number of candidates didn't show evidence of understanding the way the phases form under equilibrium conditions.

2. Compare the properties of ductility and hardness of the two steels, explaining the differences in terms of their microstructures.

Too many candidates explained the difference in properties to be simply due to an increase in carbon content without making reference to the type and distribution of the phases.

Ductility: 0.6% is more ductile because it has a greater amount of α *than 1.3% C steel.*

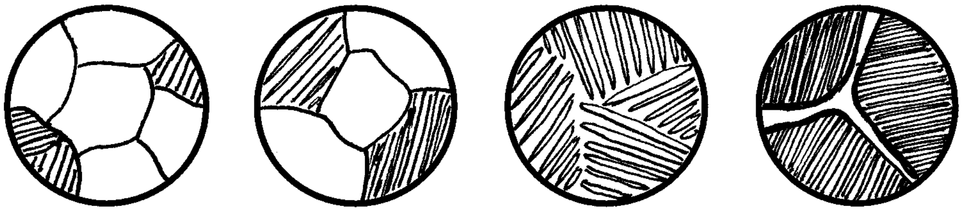
Hardness: 1.3% C steel is harder because of the larger amount of cementite.

Candidates need to have a good understanding of the phases present in the steel portion of the iron–carbon diagram. For example

ferrite	=	soft, ductile and readily cold works, low tensile strength
Fe_3C	=	cementite – hard brittle compound of iron and carbon. It is the hardest structure on the diagram.
ferrite + Fe_3C	=	pearlite – eutectoid composition which contains 0.83%C. It has alternating bands of ferrite and cementite. The ferrite is the continuous phase.

Note: Pearlite is less ductile and much harder than ferrite, therefore the more pearlite, the harder, less ductile and increased strength properties the steel has.

Candidates need to be able to draw microstructures for each of the steel groups.



0.2%C 0.4%C 0.8%C 1.2%C

Microstructures should indicate the varying proportions of phases present in the annealed condition. Depending upon the magnification used to observe the pearlite, it may appear as plates of cementite in pearlite(high magnification) or dark and unresolved (low magnification). Note 0.8% sketch shows the cementite in the pearlite as plates. As the ferrite in pearlite is a continuous phase, grain boundaries are often indistinct in annealed low carbon steels in the annealed condition, ie the ferrite 'flows' from the primary ferrite grains into the pearlite area.

(iv) Cementite is an interstitial compound of iron and 6·67% carbon. Its formula is Fe_3C.

1. Define interstitial compound.

A chemical combination of a metal and a non-metal where there is a large difference in atomic diameters.

Well answered in terms of understanding the meaning of 'interstitial', however, few candidates clearly understood a definition of 'compound'.

2. Explain the relationship between the structure and the properties of cementite.

A large number of candidates merely repeated the information from the question, stating that cementite, being interstitial, is therefore hard and brittle. This was adequate to answer the question.

The large number of carbon atoms in the interstices between the iron atoms causes hardness and brittleness.

Candidates need to have a sound understanding of solid solutions and compounds in alloys. eg interstitial and substitutional solid solutions, they need to understand the relationship between solute and solvent atoms and the part atomic radii play in these alloys.

(v) Annealing and tempering of glass involves different cooling rates. Describe how these different cooling rates produce different properties.

A number of candidates described the processes of tempering and annealing without including how the process produces the properties.

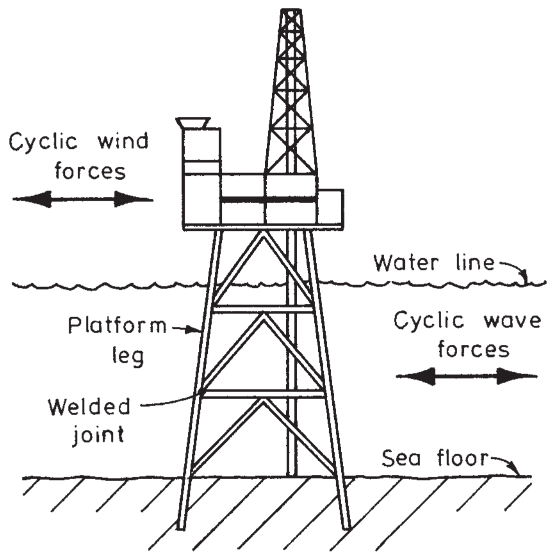
Annealing of glass involves reheating to the transition temperature to relieve the stresses from manufacturing. This is followed by slow cooling.

Tempering involves reheating and rapid cooling of the surface which places the surface in compression. Tempered glass is tougher and more crack resistant than annealed glass.

This section deals with the effects of Heat Treatment on Glass — the mechanical properties of glass can be altered by two different types of heat treatment.

1. Annealing is used to remove the stresses formed during manufacture. If the glass is not annealed it would be weak and brittle and not stand up to normal applications.
2. Tempering is carried out on the glass to make it tougher and more crack resistant on its surfaces.

(b) The offshore structure shown below is subjected to cyclic loads from both wind and waves throughout its life. The platform legs are constructed of structural steel, free from impurities. The welded joints on the platform legs have developed cracks, as observed by divers during routine inspections.



NOT TO SCALE

(i) Name and describe the type of corrosion that would occur at the cracked welded joints.

Concentration cell corrosion - lower oxygen concentration at the bottom of the crack causes an anode. The higher O_2 concentration on the surface is the cathode.

Better candidates recognised the fatigue resulting from the cyclic loading, and thus the development of stress corrosion. Candidates who considered the crack in the weld itself, recognised the development of a concentration cell. More obscure, though acceptable was a response of ‘erosion corrosion’. A number of candidates could name the type of corrosion but not accurately describe the process. The tidal area would be extremely susceptible to corrosion, due to variations in oxygen and water.

(ii) Name and describe one type of corrosion that may occur on the platform legs.

Galvanic microcell formed in pearlite. This would cause differential corrosion between the ferrite and cementite.

Intergranular attack – type of submicroscopic galvanic corrosion along grain boundaries.

Reasonably well answered, but again, candidates were not able to clearly describe the process.

(iii) Name and describe TWO preventative measures that could be used to reduce corrosion on the platform legs.

Well answered although many candidates described the method of protection without naming the method. Replacement of the legs altogether with a different material was not acceptable as a method of protection. A number of candidates who responded with 'paint' as a protective method, did not describe how the paint actually provides protection.

Method 1 Sacrificial anode

An anode of higher activity usually zinc or magnesium is placed in close contact and provides cathodic protection.

Method 2 Impressed voltage

An impressed d.c. voltage is provided to the legs from an electrical power source causing the legs to be cathodic.

This part tests candidates' knowledge of why corrosion may occur and how you would protect metals against corrosion.

Candidates preparing themselves for the H.S.C. exam should have a sound understanding of the following:

- corrosion — electro-chemical (wet)
  direct chemical (dry)
- factors influencing corrosion
- specific corrosion types
- methods of protecting against corrosion
- passivity of metals
- electrode potential
- galvanic cells
- galvanic series

SECTION II

(15 marks)

Attempt THREE questions.

Each question is worth 5 marks.

QUESTION 3

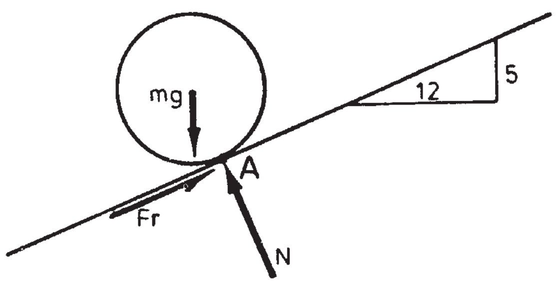
The 30 kg wheel has a diameter of 500 mm and a radius of gyration of 300 mm about point A, the instantaneous point of contact between the wheel and the incline. The forces acting on the wheel as it accelerates down the incline without slipping, are shown in the diagram.

This question tested candidates' knowledge of circular motion, the relationship between Moment of Inertia and Radius of Gyration as well as the action of friction causing the wheel to roll down the incline.

Candidates first were required to find the sum of the moments about the point of rotation, 'A'. This is the Torque acting on the wheel. The moments can be found by multiplying the component of weight force down the slope by the radius (250) or by multiplying the weight force (30×9.8) by the perpendicular distance ($500 \sin\theta$).

Candidates need to practise summing moments about a point in a variety of force diagrams as many candidates seemed to be overawed by the diagram and could not successfully complete a straightforward moment manipulation.

(a) (i) Determine the sum of the moments about point A.



$m = 30\ kg$

$\sin\theta = \dfrac{5}{13}$

$\Sigma M_A = mg \times \sin\theta \times r$

$= 30 \times 9.8 \times \dfrac{5}{13} \times 0.25$

$= 28.26\ Nm$

Moments $\quad 28.3\ N\ m$

(ii) Determine the moment of inertia about point A.

This part asked candidates to determine the Moment of Inertia knowing the Radius of Gyration.

A significant number of candidates confused the radius of gyration 'k' with the actual radius of the wheel. Another common mistake was to assume that the 'k' given was about the centre. Realising that the Radius of Gyration was about point A allowed for simple substitution into the formula $I_ç = mk^2$.

$k = 0.3\ m$ $\qquad I_A = mk^2$

$= 30 \times 0.3^2$

$= 2.7\ kgm^2$

Moment of inertia $\quad 2.7\ kg\ m^2$

(iii) Determine the angular acceleration of the wheel as it rolls down the incline.

This part of the question tested the concept of angular acceleration produced by torque.

A majority of candidates did not realise that the sum of the moments calculated in part (I) is the Torque acting on the wheel. A simple substitution into the T = Iα equation, using the previously calculated values, gave the correct answer.

$$\Sigma M_A = I_A\,\alpha$$

$$\alpha = \frac{\Sigma M_A}{I_A} = \frac{28.3}{2.7}$$

$$= 10.48\ rad/s^2$$

Angular acceleration $\quad$ ***10.48*** *rad/s*^{2}

(b) Determine the frictional force acting on the wheel during its downhill roll.

Candidates were required to find the frictional force from a given free body diagram by finding the unbalanced force that caused acceleration along the plane.

This part of the question was poorly answered as candidates found difficulty in relating the unbalanced force along the plane (mgsinθ – Fr) to the tangential acceleration of the point in contact (ma_x). Candidates need to practise applying the concept of $\Sigma F = ma$ in a variety of situations.

x $\swarrow$ $\quad \Sigma Fx = ma_x \qquad a_x = r\alpha$

$$mg\sin\theta - F_R = mr\alpha$$

$$30 \times 9.8 \times \frac{5}{13} - F_R = 30 \times 0.25 \times 10.48$$

$$F_R = 113.19 - 78.6$$

$$= 34.6$$

Frictional force $\quad 34.6\ N$

QUESTION 4

The crate shown in the diagrams below has a mass of 120 kg. The plane is inclined at an angle of 20° to the horizontal. A horizontal force P is applied as shown.

This question required candidates to analyse both the frictional forces acting on the crate on the slope and the resulting acceleration caused by the unbalanced forces acting along the slope.

(a) Determine the minimum value of force P required to hold the crate on the plane. The coefficient of static friction between the crate and the plane is 0·15.

This part required candidates to determine the force P necessary to hold the crate in equilibrium.

Most friction problems can be analysed by either using components of forces acting along and perpendicular to the plane or by considering total forces which lead towards a concurrent force diagram resulting in a graphical solution. The graphical solution would have been the quickest in this situation.

Many candidates that used the component approach did not include the component of the applied force (Psin 20˚) in the expression for N. It is important to practise the summing of forces parallel and perpendicular to the plane in a variety of situations.

$\Sigma F_{\text{Perpendicular to the plane}} = 0$

$0 = N - P \sin\theta - 120 \times 9.8 \cos 20^\circ$

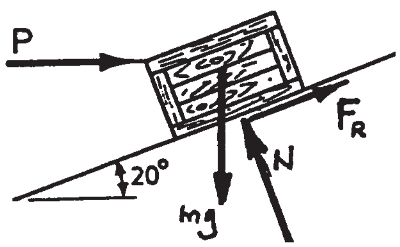
$N = 0.342P + 1105.1$

$\Sigma F_{\text{Perpendicular to the plane}} = 0 = P \cos 20^\circ + mN - 120 \times 9.8 \times \sin 20^\circ$

$0 = 0.9397P = 0.15\ (0.342P = 1105.1) - 402.2$

$0 = 0.0991P - 236.45$

$P = 238.6\ N$

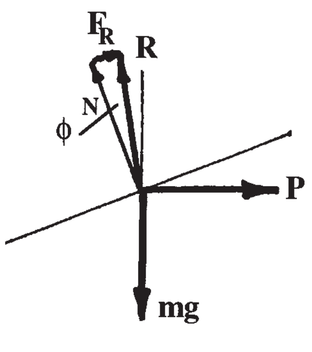


$\tan\phi = \mu$

$\phi = 8.53^\circ$

$\theta - \phi = 20 - 8.53$

$= 11.47^\circ$



$P = mg \tan 11.47^\circ$
$= 120 \text{ x } 9.8 \tan 11.47^\circ$
$= 238.6\ N$

Force P   *238.6 N*

(b) Determine the magnitude of the force P required to maintain a constant acceleration of 0·4 m/s^2 up the plane. The coefficient of dynamic friction between the crate and the plane is 0·12.

Candidates were tested on their ability to analyse unbalanced forces causing motion along the plane.

A clear free body diagram which included components of all forces acting along and perpendicular to the plane was important if candidates were to correctly sum the forces along the plane. The direction of the frictional force is opposite to the previous part as the motion is up the plane.

A large number of candidates didn't include Psin 20˚ in the calculation of the normal force and simplified the solution. Others did not correctly resolve the components of the weight force and the force P.

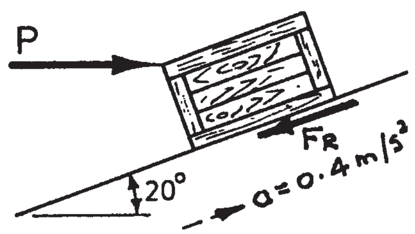
A typical incorrect solution which omitted Psin 20˚ is shown below.

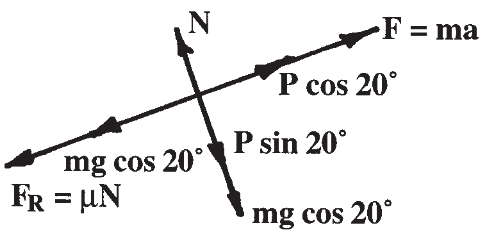
$P\cos 20^\circ - \mu N - mg \sin 20^\circ = ma$

$P\cos 20^\circ - \mu\,(120 \times 9.8 \cos\theta) - 120 \times 9.8 \sin 20^\circ = 120 \times 0.4$

$P\cos 20^\circ - 0{,}12 \times 1105.1 - 402.2 = 48$

$P = 620.2\ N$





$$F = ma$$

$$= P \cos 20^\circ - mg \sin 20^\circ - \mu\,(P \sin 20^\circ + mg \cos 20^\circ)$$

$$120 \times 0.4 = 0.9397P - 120 \times 9.8 \times 0.342 - 0.12(0.342P + 120 \times 9.8 \times 0.9)$$

$$= 648.6\ N$$

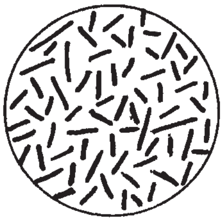
Magnitude of force P ***648.6*** *N*

QUESTION 5

Two samples of 0·5% carbon steel were heated to 50°C above their upper critical temperature (UCT), soaked, then quenched to room temperature at a rate exceeding their critical cooling rate.

(a) Sketch and label the resultant microstructure.

Well answered, although there was a wide discrepancy in candidate's ability to represent martensite as a fine needle like structure.



QUENCHED 0·5% CARBON STEEL

(b) Briefly describe the mechanical properties of the quenched 0·5% carbon steel.

Well answered, most candidates recognised the resultant structures as hard and brittle. Some candidates however, stated 'hard, brittle and tough' as a conflicting answer.

Hard and Brittle.

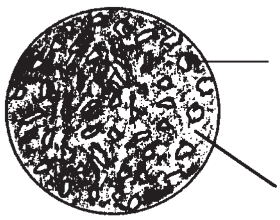
(c) Sample 1 was reheated to 220°C, soaked for 45 minutes, then cooled to room temperature.

Sample 2 was reheated to 670°C, soaked for 45 minutes, then cooled to room temperature.

(i) Sketch and label the final microstructure of each sample.

Not well answered. Candidates evidenced poor understanding of the subsequent heat treatment of martensite, particularly of spherodisation.

SAMPLE 1



SAMPLE 2

(ii) Explain, in terms of structure, the difference in mechanical properties of the two heat-treated samples.

Better candidates recognised the difference between physical and mechanical properties, and stated that spherodised steel is machineable due to the continuous alpha phase, and that tempered martensite retains hardness and therefore abrasion resistance, while increasing toughness or shock resistance.

Tempered martensite retains its hardness and increases toughness.

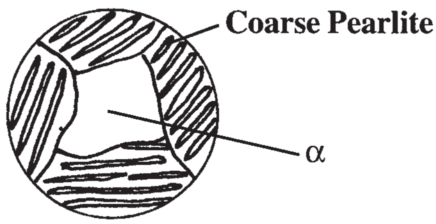
Spheroidised steel is much softer due to the continuous phase of α. It therefore has increased machineability.

(d) Sample 1 was reheated to 800°C, soaked for 45 minutes, then very slowly furnace cooled to room temperature.

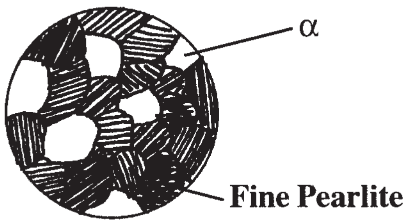
Sample 2 was reheated to 800°C, soaked for 45 minutes, then air cooled to room temperature.

(i) Sketch and label the final microstructure of each sample.

Well answered, although diagrammatic representation varied in quality. Many candidates knew about a difference in grain size but did not accurately represent a difference between coarse and fine pearlite.



SAMPLE 1



SAMPLE 2

(ii) Explain, in terms of structure, the difference in mechanical properties of the two heat-treated samples.

Sample 1 has large grains of soft and ductile ferrite and wider regions of ferrite in the coarse pearlite.

Sample 2 contains smaller grains of ferrite and narrow regions of ferrite within the pearlite.

Sample 1 is softer and more ductile than sample 2.

This question deals specifically with the heat treatment of steel. The following processes were examined.

• hardening; • tempering; • spherodising; • annealing; • normalising.

All heat-treatment processes consist of three parts:

1) The heating of the metal to a pre-determined temperature.

2) The soaking of the metal at that temperature until the structure becomes uniform.

3) The cooling of the metal at a pre-determined rate which will form predictable structures within the metal.

Candidates should have:

- a sound knowledge of the three parts of each process
- draw and label correctly all phases in the resulting microstructures
- a good understanding of the physical and mechanical properties

For example Hardening — heat into Austenite range
— soak
— quench

resulting microstructure — martensite — hard brittle structure

Candidates should prepare simple summaries (as above) on each of the heat treatment processes.

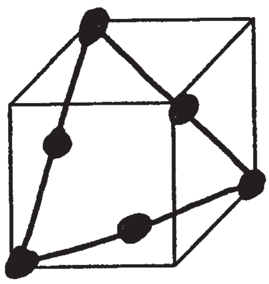
QUESTION 6

(a) Copper has a face-centred cubic structure.

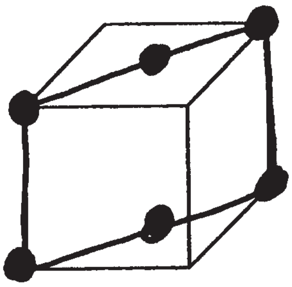
(i) On the sketches given below, draw the (111) plane and the (110) plane.

(ii) Indicate, on the sketches given below, the position of the centres of all the copper atoms that lie on each of these planes.

Candidates confused BCC and FCC in their inclusion of atoms centres. A large number of candidates omitted answering this part of the question.



(111) PLANE



(110) PLANE

(iii) Explain why slip occurs more readily on the (111) planes of copper than on the (110) planes.

Many candidates recognised the parametral plane as having higher density. Some candidates however confused density with the number of atoms rather than interatomic spacing.

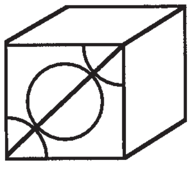
Slip occurs on planes of higher atomic density and will therefore occur more readily on the (111) plane which has 6 atoms but a smaller area than the (110) plane.

Candidates need to understand plane representation in the unit cell. A good method of achieving this is to use a clear plastic box and fill it with the same size spheres such as ping pong balls. Candidates can then better visualise the unit cell as a representative of the lattice structure.

Candidates need to be able to diagrammatically isolate the unit cell for both FCC and BCC coordination and thereby understand the atomic centres appropriate to the structures.

With respect to the occurrence of slip in the planes, candidates need to understand that both planes have the same number of atoms but differ in density ie proximity of atoms to each other.

(b) Aluminium has an atomic radius of 1·431 Å and a face-centred cubic structure. Determine the size of the unit cell.



$$d = 4 \times r = 4 \times 1.431 = 5.724\ \text{Å}$$

$$\sin 45^\circ = \frac{x}{5.724}$$

$$= 4.047\ \text{Å}$$

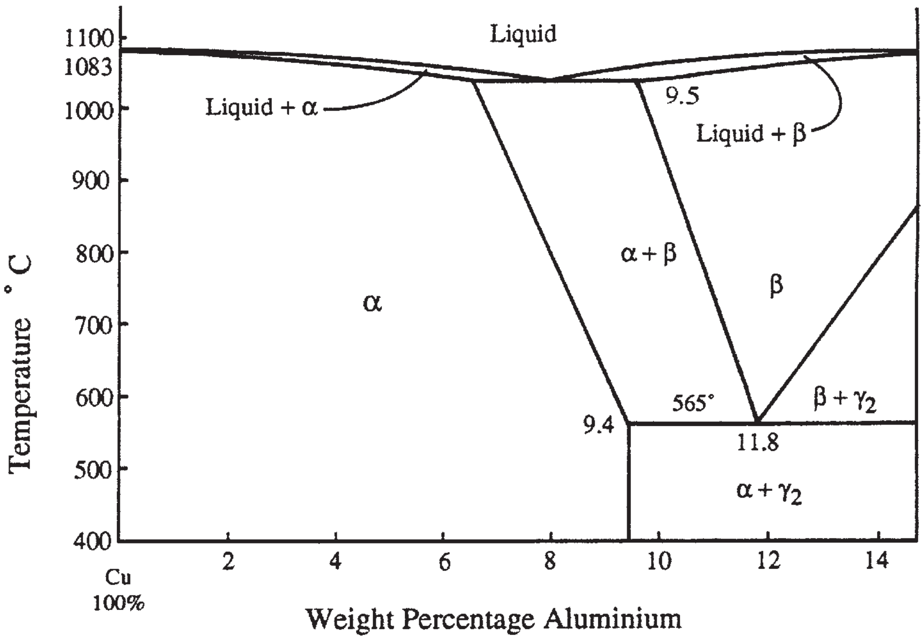
Reasonably well answered, although a number of candidates evidenced understanding of the cell configuration but then erred in the mathematic operation.

Size of the unit cell = ***4.047*** *Å*

Candidates often have difficulty conceptualising the three dimensional unit cell. It is important to use graphical representations to show the configuration of atoms and part-atoms so that candidates can understand the relationship between atomic radii and the size of the unit cell.

Candidates also need to grasp basic trigonometric mathematics so as to substitute values from the atomic radii to determine unit cell size.

(c) The copper rich portion of the copper–aluminium equilibrium diagram is given below.



The maximum solubility of aluminium in copper is 9·4% and occurs at 565°C. The eutectoid composition is 88·2% Cu–11·8% Al and the eutectoid temperature is 565°C.

(i) Explain the significance, if any, of the above data with reference to the heat treatment of aluminium–bronze alloys.

Very poorly answered. Candidates evidenced difficulty understanding how to 'explain significance'. Many candidates simply described the phase diagram, or made reference to the single phase portion and work hardening.

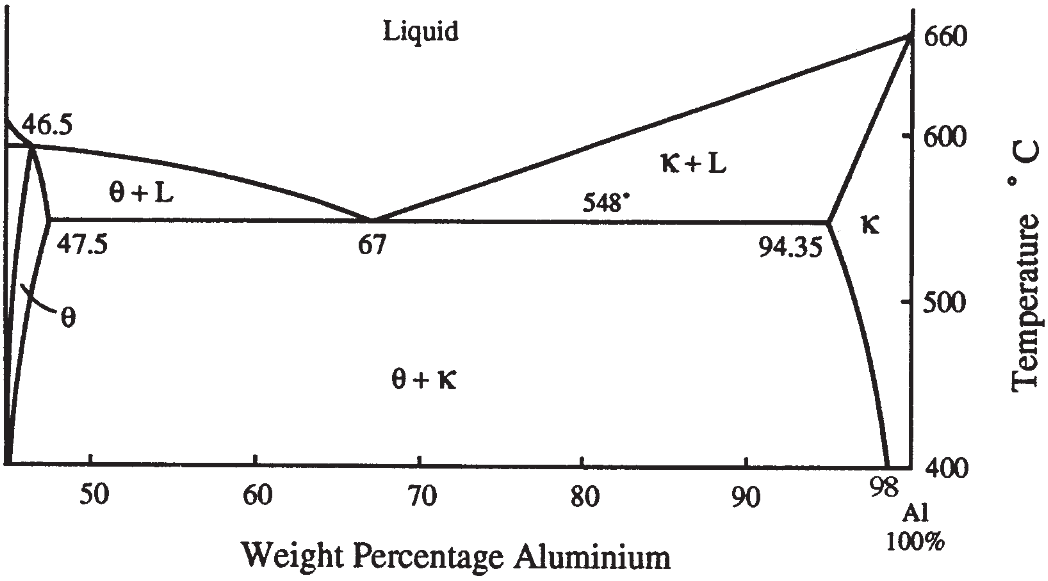
The β phase, with composition between 9.5 - 11.8 %, when quenched produces a martensitic structure.

(ii) Briefly describe the method of hardening aluminium–bronze alloys by heat treatment.

Poorly answered. Many candidates answered in terms of *'Age Hardening'* thereby failing to recognise the proper treatment for Al-bronze.

The aluminium bronzes are heat treated by heating into the β region and then quenching.

(d) The aluminium-rich portion of the copper–aluminium equilibrium diagram is given below.



The maximum solubility of copper in aluminium is 5·65% and occurs at 548°C. The eutectic composition is 67% Al–33% Cu and the eutectic temperature is 548°C.

(i) Explain the significance, if any, of the above data with reference to the heat treatment of duralumin.

Poorly answered. Many candidates referred to the eutectic composition, and thereby evidenced poor understanding of the composition for duralumin, typically 4% copper in aluminium.

The heat treatable alloy must have a composition below 5.65% Cu to allow it to be heated into the κ region. Heating to around 548˚C will allow this transformation.

(ii) Briefly describe the method of heat-treating duralumin.

Well answered by those who recognised Age Hardening as the appropriate heat-treatment for duralumin.

Duralumin is heat treated by heating into the κ range, soaking followed by quenching and aging.

Candidates need to have a thorough grasp of the Al-Cu phase diagram for the commercially useable portions and be able to identify the bronzes from duralumin so as to select the appropriate heat-treatment for a given composition.

Similar to all phase diagrams, candidates need to understand the significance of single phase portions as distinct to multiple phase portions of the diagram.

Candidates should also recognise the uniqueness of particular sections of the phase diagram where unique precipitates distinguish the alloy and it’s heat treatment.

SECTION III

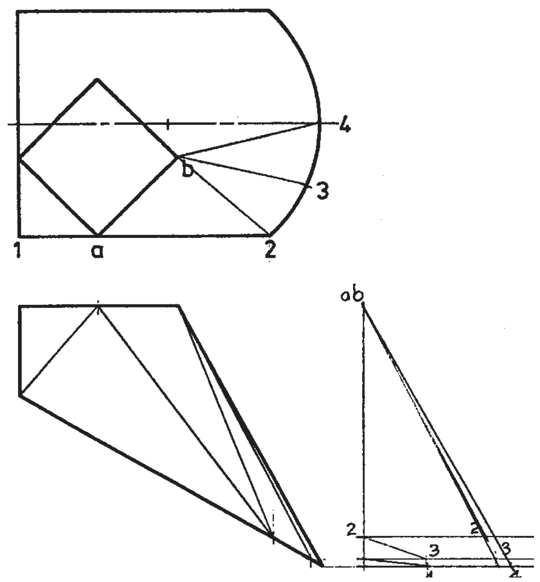
(15 Marks)

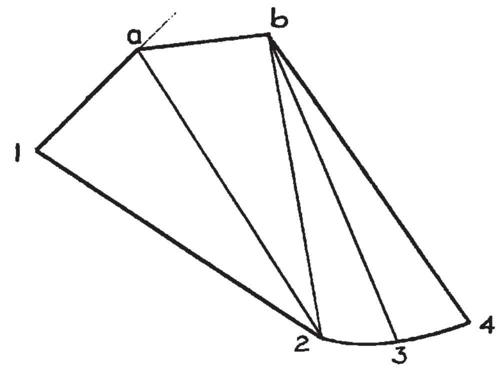
Attempt THREE questions.

Each question is worth 5 marks.

QUESTION 7

The top view and front view of a transition piece are shown below in third-angle projection. Draw a pattern for the surface a1234b. The starting position for a1 is indicated below.





The question was generally well attempted with many candidates scoring maximum marks. Most problems occurred with the varying heights in the true length diagram and failure to determine the true lengths of lines 2,3 and 3,4. Curved edges in the drawing should be drawn as a curve on the development.

Marking procedure

Evidence of appropriate triangulation.

Evidence of the projection of reference points (2 or 3) from the top view to the front view.

Calculation of a true length.

Triangulation lines are not essential but assist in understanding the problem.

When finding a number of true lengths, true length diagrams are best drawn clear of other views and labelled to avoid confusion in identifying true lengths.

Projection, rather than measuring, will assist with accuracy. Note: True lengths of 2,3 and 3,4 must be found.

Use calculated true lengths to draw the development.

Commence the development with triangle a,1,2.

This triangle may be drawn using lines taken directly from the front view where they are true length.

Construct the three remaining triangles to accurately reflect the true lengths.

Complete the outline including the curve.

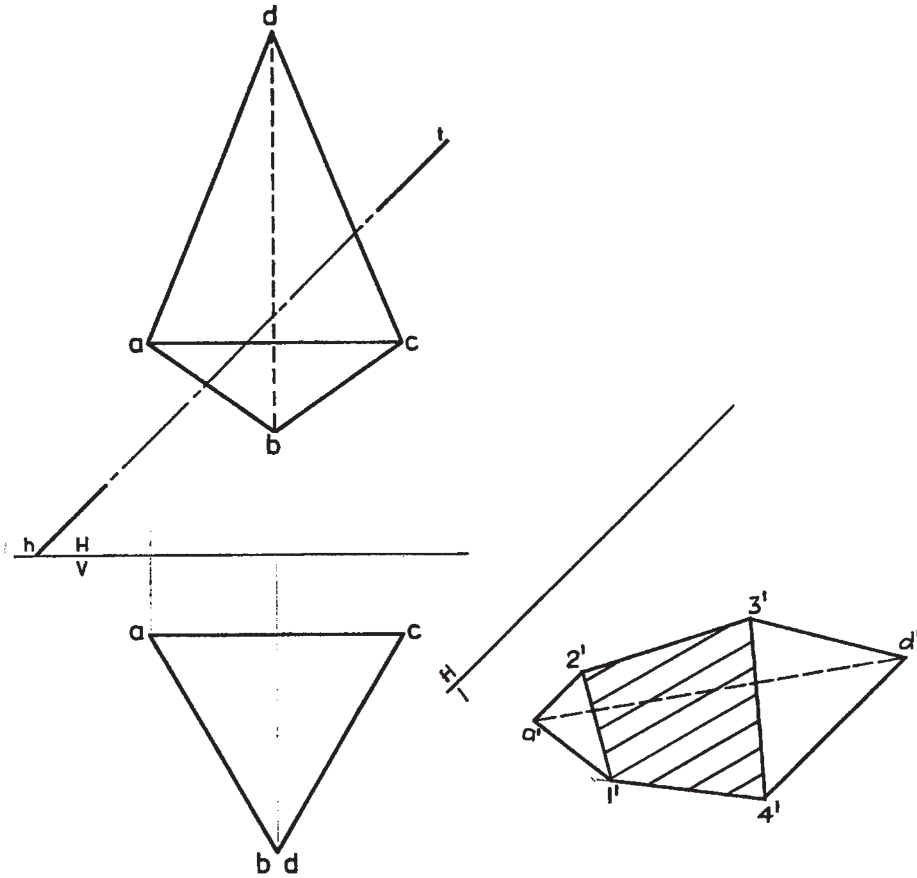
Thick, black outlines are required with thin, black fold lines.

A symmetry line must not be used as the development is not a half pattern.

QUESTION 8

The top view and front view of a triangular pyramid are shown below in third-angle projection. A vertical cutting plane is positioned as shown in the top view.

Project from the top view a sectional front view of the pyramid if the slant edge bd remains horizontal and the base edge ac makes an angle of 45° to the principal vertical plane. The apex is behind and to the right of the centre of the base.



There were occasional well drafted, accurate solutions but a poor understanding of solid geometry concepts led many candidates to either avoid this question or to produce incorrect and inaccurate solutions.

Draw an auxiliary vertical plane at 45˚ to line a,c.

Rotating the solid in the top view and projecting a new front view was used by some candidates but direct projection of an auxiliary view produced a more easily determined solution.

Some candidates did not recognise that a,c was true length in the top view and they attempted to find the apparent angle of the auxiliary plane. This was incorrect.

Project all points from the top view, for the new front view, perpendicular to the auxiliary plane.

Candidates should number the points on the section and letter the points on the solid for reference and to assist with interpretation.

Determine the heights of a and d from the original front view.

Candidates should also locate points b and c and then draw the new front view in light construction. Projection of the section points does not require reference to the original front view using this method.

Project the sectional shape.

Candidates must complete the sectional view including the part of the solid behind the section plane.

Indicate correct visibility.

This is achieved by showing the line a1,d1 in hidden detail.

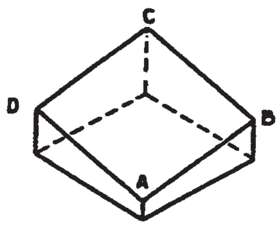
The drawing must be completed to show the sectional shape clearly at the front.

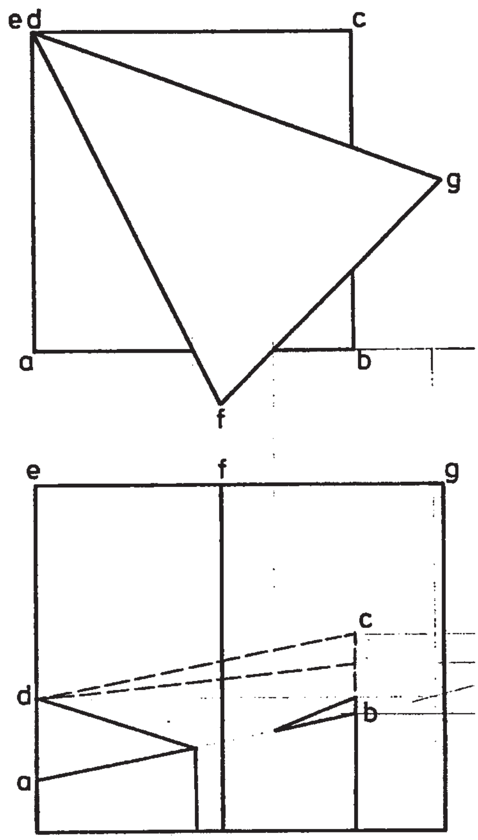
Linework must reflect standards.

Thin, black hatching lines which are equally spaced. Outline should be thick and black.

QUESTION 9

The top view and incomplete front view of a triangular prism intersecting a truncated square prism are given below in third-angle projection. A pictorial drawing of the truncated square prism is given to assist visualisation. Complete the front view.





Visualisation of the intersecting solids was achieved by most candidates who attempted this question. There was, however, a poor understanding of the method of determining heights of intersection of on the edge c,d as this required the use of an auxiliary view.

There were some innovative alternative solutions mostly involving cutting planes parallel to edge a,b.

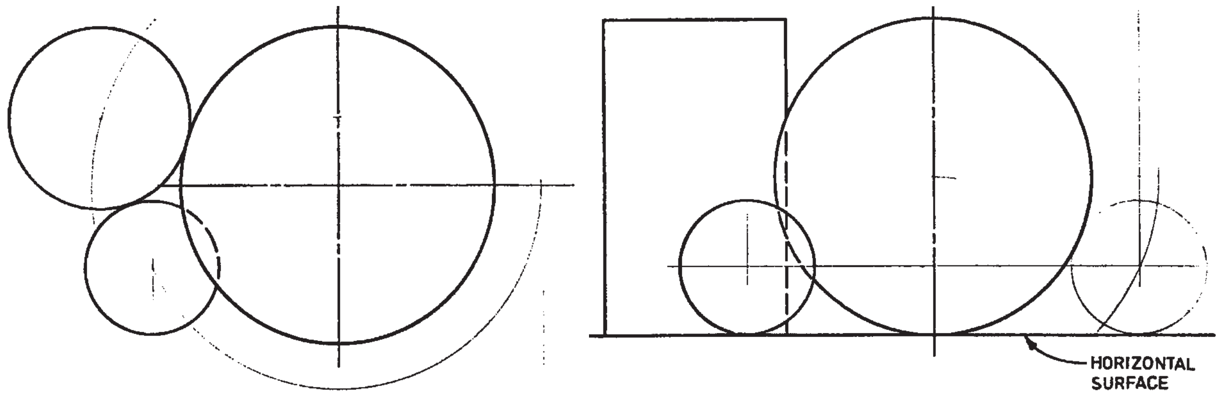
Half a mark was awarded for each of the nine significant lines in the correct solution. The other half mark was awarded for differentiation between the outline and hidden detail lines.

QUESTION 10

The top view of a sphere is given below. The sphere rests on a horizontal surface. A cylinder, diameter 40 mm and length 70 mm, stands on its end on the horizontal surface and touches the sphere. The centre of the cylinder is to the left and 15 mm behind the centre of the sphere.

A second sphere, diameter 30 mm, also rests on the horizontal surface, touching both the sphere and cylinder. It is in front of both the cylinder and the sphere.

Complete, in third-angle projection, the top view and front view of the cylinder and the spheres.



Candidates who attempted this question were able to visualise the relationship between the solids but often had difficulty positioning the small sphere. The positioning of this sphere was best achieved through the use of an auxiliary view. A knowledge of tangency and methods of determining centres and points of contact as well as the use of auxiliary views is essential to attempt drawings of this type.

Position the top view of the cylinder:

Tangent to the sphere.

15mm behind centre.

Project the front view of the large sphere.

Project the front view of the cylinder.

To locate the small sphere:

Use an auxiliary view of the small sphere in contact with the large sphere in the front view. This will allow the determination of the radius on which the centre of the sphere lies in the top view.

Project and then rotate this axis in the top view.

Add the radii of the small sphere and the cylinder to determine the centre of the small sphere in the top view.

Draw the top view of the sphere.

Project the small sphere to the front view.

Show the correct visibility of the three solids in both views.

Hidden detail must be used to show the correct overlap of the three solids.